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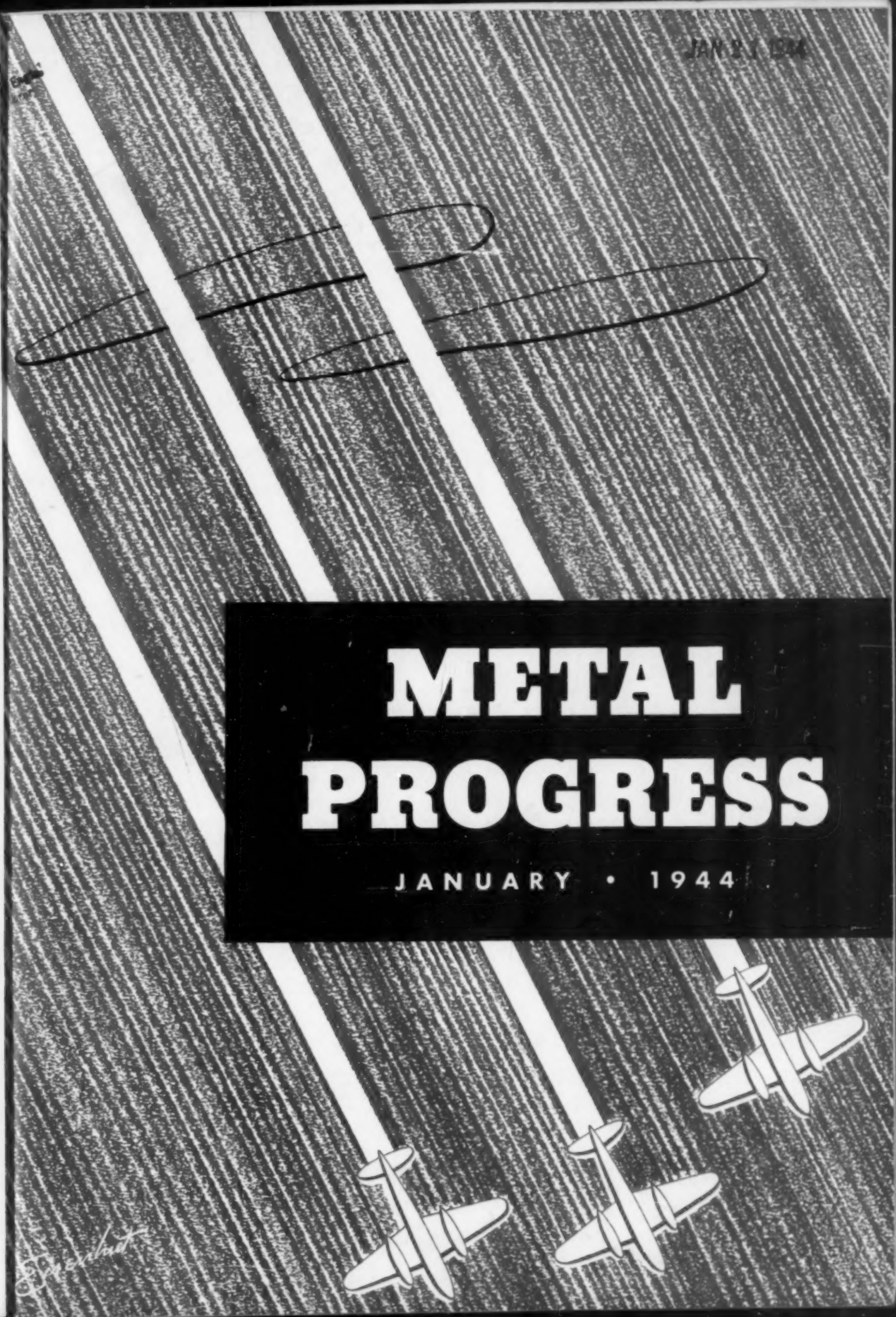

METAL PROGRESS

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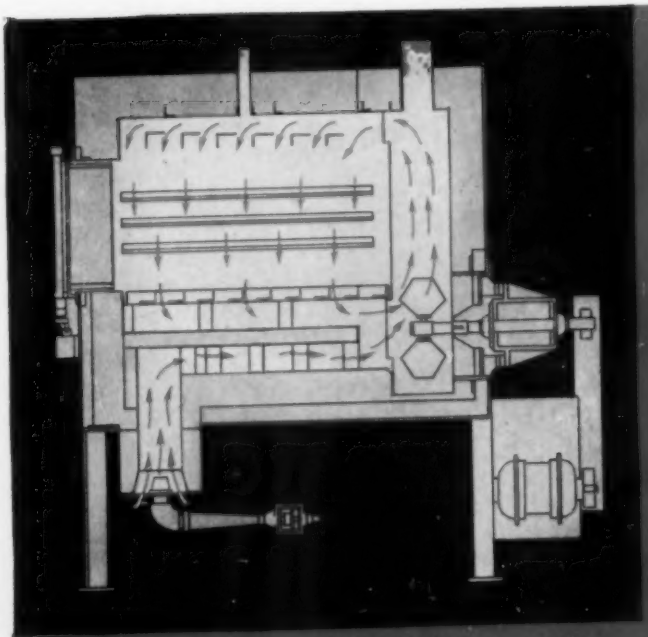
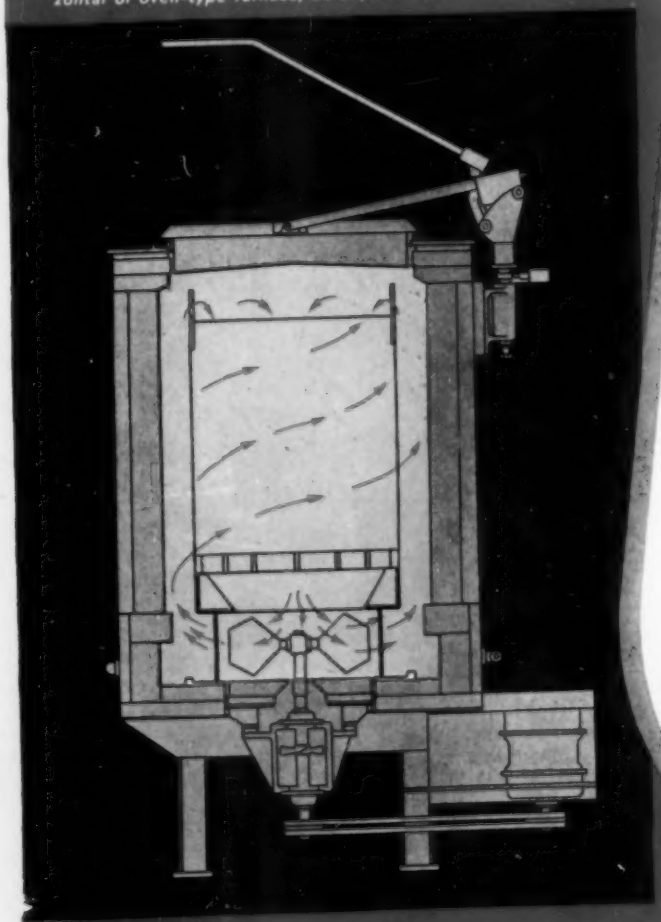


The circulation of hot gases in Surface Combustion convection furnaces is shown in these two illustrations. Above is the horizontal or oven-type furnace; below, the vertical or pit-type.



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This is Part I. Part II (separate) is the "Where-to-Buy" Section

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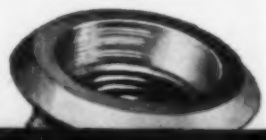

Metal Progress

Volume 45 *1944*

Metals and the War

A stirring tale of cooperative effort by free American scientists, technicians, and industrialists was presented by Mr. Williams in talks given recently before the Pittsburgh and Columbus Chapters, ASM, and here briefed for all to read

ONE YEAR of preparation, two years of war and the United States has reached its production goal! This goal is far above the enemy's maximum, which required more than ten years of internal development and the conquest of most of Europe to achieve. The story of this accomplishment would be interesting telling but even the phase relating to metals would take too long for this article. This achievement is a triumph for our industrial, research and technical organizations. It is also a tribute to our people's cooperativeness, the exchange of "know-how", and contributions to the cause of technical information resulting from years of private research. In addition, our country is blessed with an abundance and variety of mineral raw materials as well as relatively easy access to most of those we don't possess.

As a result of a wise, although a short-lived, stock-piling program and our ability to keep the sea lanes open, we have been denied no metal or mineral raw material. However, the need for production on an unexpectedly large scale caused us to scratch for some, substitute for others, and conserve still other metals.

Steel Manufacture

Fortunately, our internal economy had long been based on a huge production and consumption of metals. For example, steel ingot production in 1940 had reached 66,000,000 tons and the rated maximum capacity of the industry was about 80,000,000 tons. To produce 80,000,000 tons was relatively simple. To go beyond this and to reach the 86,000,000 tons produced in 1942, and to develop the capacity to make over 97,000,000 tons now in prospect, meant the extension of normal mining and transportation facilities based largely on Lake Superior, southern and imported ores, and required the development of long-known ore bodies in New York, New Jersey, California and Texas, and an increase in production from operating mines in Utah and Wyoming.

Since our steel production has been mainly by the openhearth process and based on the use of about 50% pig and 50% scrap, it became necessary to find greatly increased amounts of "home" scrap. The nation has responded to this need to an astonishing degree. In addition, the blast furnace departments have greatly increased output of pig iron by better preparation of ore, harder blowing and increased use of scrap, in spite of poorer coke quality, in many cases, due to pushing the ovens literally beyond their limit.

The speed with which enormous blast furnaces have been built and put into operation, and the complete failure of any of the sponge iron proposals to materialize even as interesting

By Clyde Williams
Chairman, War Metallurgy Committee
Director, Battelle Memorial Institute

experiments more than a year after being supported by substantial grants of money, shows the fallacy of depending on anything but mass-production machinery during a national emergency. The sponge iron process was either too undeveloped or too difficult to put into operation to warrant serious consideration as a war industry, even if the unproved and doubtful claims for economies, put forward by its proponents, had been correct. Increased pig iron production, an intensive scrap collection and segregation program, and the conversion of pig iron in bessemers to make steel or synthetic scrap, are the most practical methods of dealing with so large and highly mechanized an industry.

Demand for unprecedented quantities of alloy steels created many problems in production. The nation's capacity for the construction of electric furnaces was taxed. In 1942, nearly 4,000,000 tons of electric furnace steel was made and the projected capacity to be made available in 1943 was over 6,000,000 tons. Larger furnaces than customary were built and the practice of duplexing from the openhearth to the electric furnace was evolved. Also the practice was adopted of melting scrap and pig iron in the cupola, blowing in the bessemer and finishing as alloy steel in the electric furnace. Furthermore, as our alloy supply became insufficient to meet increasing demand, low alloy steels and practices for making them in the openhearth were developed; this procedure accounted for about two-thirds of the total alloy steel produced in 1942, which was 11,500,000 tons.

Manganese and Chromium

In spite of the reduction of the alloy content of armor plate, constructional steels, and close restriction of all miscellaneous uses, the steel alloying materials were required in ever increasing quantities. We have always been dependent on foreign countries for the majority of our supply of many of the ores of the ferro-alloys. Molybdenum is an exception. For manganese, chromium, tungsten and vanadium, methods have been developed to treat domestic ores to supplement foreign receipts. Production of domestic high-grade ore and concentrates from many small deposits was encouraged by higher prices. Numerous small mills based on jigging and tabling were put into operation.

The largest resultant operation is that in Montana based on the oil flotation of a low-grade manganese carbonate. The operation in Cuba was enlarged; it uses oil flotation of manganese oxide from an ore of about 20% manganese content, a method perfected prior to 1940. This left several large, low-grade deposits in the United States which, because of their highly disseminated condition, required some form of beneficiation other than mechanical or flotation procedures.

Study of numerous hydrometallurgical flowsheets brought out the superiority of the sulphur dioxide leaching method. This procedure (which, of course, must vary for different ores) consists of roasting the ore, leaching, recovering the manganese oxide from the resultant manganese sulphate, and finally sintering to form a product containing approximately 65% manganese. Such a process is now in operation at Las Vegas, Nev., which at full production will make 300 tons of sinter a day. While it represents a practical means for supplying needed manganese, it is also looked upon as a pilot operation which with some variations may be applied to the large low-grade deposits at Artillery Peak, Ariz., and those in the Cuyuna Range in Minnesota, and in Maine.

The exceptionally high-grade nodules obtained from such operations may be mixed with below-grade ores to bring them to acceptable tenor for electric smelting. For example, the low manganese, high phosphorus ore of Batesville, Ark., and the nodules that may be obtained by screening and jigging the large lean deposits of Chamberlain, So. Dak., will find ready use in this way, if and when an emergency requires that these high-cost operations be used.

For economy of labor and materials the optimum procedure has been to use high-grade ore or concentrate and produce high carbon ferromanganese in the blast furnace and low carbon ferromanganese and silico-manganese in the electric furnace. Use of high cost electrolytic manganese is therefore justified only for limited special uses heretofore supplied by manganese metal made by silico-reduction or alumino-thermit reactions.

The situation in chromium has followed somewhat the pattern established by manganese. Importations have continued at high level. An important tonnage of concentrate has been made from low-grade ores of California and Montana, and from beach sands in Oregon. While these operations produce a sub-standard ore, due mainly to its high iron : chromium ratio and its fineness of division, the product may be used satisfactorily by mixing with high grade imported ore — or, if necessary, these difficulties may be overcome by known methods which remove the iron and put the concentrate in suitable physical form. Should it become necessary, the operations in Montana can be quickly enlarged to take care of a greatly increased demand.

Other Steel Alloys

Early in the war program, as production of war matériel increased, requirements for tungsten increased, especially for toolsteels. Thus, the substitution of molybdenum for tungsten, which had long been known but not practiced widely, became necessary. The versatility of molybdenum led to its substitution for other metals and its use in other steels to such a degree that finally it became scarcer than tungsten! Then the swing back to tungsten toolsteels began. Our imports of tungsten ore from China stopped, but important domestic production was undertaken and imports from South America were greatly increased. The output of our molybdenum mines was stepped up to the maximum possible. A substantial increment to this was the production of molybdenum sulphide as a by-product from several of our Western porphyry copper operations, a practice fortunately developed just prior to the war. Such a by-product greatly increased as the demand for copper increased, and now accounts for some 20% of our molybdenum output.

The factors that made tungsten and molybdenum scarce affected vanadium similarly. Production of this useful metal on a substantial scale was undertaken in Colorado to supplement receipts from Peru. The MacIntyre iron ore of New York State, now treated to produce titanium dioxide, yields a magnetite which contains vanadium. Processes have been worked out to recover the vanadium from the pig iron being made from this iron ore by blowing it in the bessemer and treating the slag by a chemical process. Since the iron ore also contains considerable titanium oxide, it must be mixed with other purer ores. Hence, the vanadium content of the pig iron is quite low. Another process is available which comprises roasting with alkalis and leaching out the vanadium. Either of these is ready for use should the need for more vanadium arise.

The remaining tonnage steel alloy, nickel, is so versatile and is used so widely that despite every effort at conservation and increase in production, there has seemed never to be enough. Output from the world's outstanding operations in Canada has been increased as fast as possible. Efforts also have been made to secure important amounts from the refractory Cuban iron ores which contain upwards of 1% of nickel; both pyrometallurgical and hydrometallurgical processes are under large scale development. While these represent less attractive situations than the established operations, yet they provide factors of safety that we dare not overlook.

Substitute Metals and Processes

The ferrous alloying metals above discussed, with copper, silicon and the less common ones, have all been scarce, as have practically all the metals, because of our tremendous production of metal products. In fact, to become the "arsenal of democracy", the United States was forced to produce as much as possible of all metals in the shortest period of time. This was necessary despite significant measures taken in substitution and conservation. Even though production was greatly increased, the ferrous alloying metals had to be used sparingly. The bulk use of alloys was replaced by the intelligent use of metallurgy. Again it was a case of substitution, metallurgical brains being used in place of alloy brawn.

During this period it was fortunate that our metallurgists had developed a mass of information and the industry had had production experience on low alloy steels; also that precise knowledge of the factors involved in "hardenability" had replaced ill-defined conceptions of "body", "timbre", and other words meaning "quality". As a result, there emerged almost overnight the long list of useful National Emergency steels which could be and were changed in composition to fit the ever-changing balance of supply of the different alloys. Thus, the huge tonnage of constructional steels could be made from the low alloy National Emergency compositions instead of the higher alloy S.A.E. grades. Similarly, substantial reduction in the manganese content in many steels used in the upper hardness brackets, followed improvements in heat treatments. Heat treating cycles involving a drastic quench enabled Americans to make satisfactory armor plate from low alloy steel.

Other examples of substitution have been the use of new production methods to replace or to supplement existing methods. One example is the conversion of continuous strip mills to make heavier plate. The casting of armor plate and turrets has greatly increased the production of tanks. Welding of tank armor replaced riveting. Both schemes resulted in improvement. Many parts made of steel castings replaced forgings that required extensive machining; this relieved the requirements for both forging facilities and machine tools. An example of this is aircraft cylinders made by centrifugal casting. The new precision casting method, first applied to the forming of intricate shapes of highly alloyed steel, is now being adapted to small parts of low alloy and mild steel. A wide extension of old welding procedures and the development of new ones have put this method of fabrication,

which was rarely used in the last war, almost in a field by itself. Similarly, brazing of minor components into complex assemblies has been widely adopted to save weight or lessen machining. Although powder metallurgy has been extended to the production of many intricately shaped parts of ferrous and non-ferrous metals, it has not been as widely adopted as some had anticipated.

The Situation in Copper and Zinc

As with ferrous materials, the non-ferrous metals (with the possible exception of lead) have had to be conserved. Even copper — and Britain and America control most of the world's output of this vital metal — has had to be used parsimoniously. The major uses are for electrical equipment, electrical transmission, and cartridge cases, driving bands and bullet jackets. Each has presented difficult problems in substitution. Silver has been used instead of copper as electrical conductors in some of the Government-owned aluminum and magnesium reduction plants. Gilding metal (90% Cu, 10% Zn) bullet jackets are being replaced by steel, clad with gilding metal, 15% on the outside, 5% on the inside. (The scrap produced in the operations is treated for recovery of copper and steel by dissolving the copper and zinc in cupric-ammonium carbonate solution, precipitating the copper as oxide, and smelting it to metal.)

The steel cartridge case, developed quite rapidly in this country, has relieved the stringency in copper to a substantial degree. Germany, of course, developed this even in the last war. Our guns are designed for the use of brass cartridge cases, and so we must fit the steel case to the gun. The trouble with steel is that its modulus of elasticity is about twice that of brass. When the brass case is fired it expands and fills the breech, then it contracts quickly and is readily ejected. The high modulus of steel therefore must be counteracted by giving the steel a high yield strength; over 100,000 psi. is believed to be necessary. In relatively short time several methods of fabrication which give the desired properties have been worked out. The high strength properties are secured by cold working plain carbon steel, a variety that can be readily formed. In other schemes, plain carbon or low alloy steel is hot worked and finally heat treated to develop the necessary properties.

About the same situation existed for zinc as for copper, its principal use being in cartridge brass. It is interesting to observe that during the early days of our preparedness program, copper and zinc had not been considered strategic metals. In fact, it had been assumed that there would be an ample supply of these metals, but nearly everyone failed to realize the tremendous scale of our war production program.

Tin, a 100% Importation

On the other hand, tin, which with manganese, was expected to head the list of strategic materials, is, like manganese, being taken care of very satisfactorily. First a wise stock-piling program was adopted, so that a substantial backlog of tin was available at the time of Pearl Harbor. Also, in the fall of 1940, plans were put into effect for the construction of a tin smelter in Texas for smelting low grade Bolivian ores. The ore, which comes from many mines, much of it being the result of concentration, is extremely variable in composition. Because of this, because the tin content is low (18% to 65%, averaging about 40%), and because it is contaminated with such impurities as antimony, zinc, arsenic, tungsten, iron and sulphur, the smelting process is more complicated than when the pure high grade (70% tin) East Indian ores are treated. Nevertheless, a high grade product that satisfactorily equals the best Straits tin is being made. For the sake of economy, impurities are not brought down to this low point when making tin for some bronzes, bearing metals and solders.

Detinning facilities were increased and can shredding machinery provided to take care of the tin cans received from the scrap metal salvage campaign. This resulted not only in an increase in secondary tin but also in an important amount of steel scrap (which made a satisfactory melting stock, except for its content of about 0.25% lead remaining from the solder).

In addition to these steps, an effective tin conservation program was outlined even before Pearl Harbor and gradually put into effect. Noteworthy substitutions of other metals have saved much tin in the older bronzes, babbitts, bearing metals and solders.

A striking development has been in bearing metals. Tin-base babbitt is still used in numerous applications, but in the diesel and automotive fields (and in other applications) lead-base alloys with only 1 to 10% of tin are used. They contain substantial amounts of antimony (10 to 17%) and various amounts of copper, arsenic and silver. For aircraft, the electrodeposited silver bearing is used. The use of silver in bearings has gone up in two years from practically nothing to 25 million troy ounces in 1943. The magnitude of this is grasped when it is considered

that the largest industrial use in the same year was 30 million ounces for sterling and plated silverware, and 20 million ounces for photographic goods.

The tin content of solders has been arbitrarily reduced to 20 to 30% and tin-base solders are being replaced altogether for making tin cans by the 2½% silver, 97½% lead alloy. Besides this, tremendous savings in tin are made in the essential tin can by replacing hot-dip tin plate, containing about 1.5% tin, with electrodeposited tin plate having from ⅓ to ½ this amount.

Alumina and Aluminum

For the older metals whose uses and metallurgy had become quite well established, the shifting problems of scarcity have been solved largely by substitution of a less scarce metal or a change in metallurgy. For the newer metals, aluminum and magnesium, demand for aircraft and the bombing program was so great and increased so rapidly that the problem became almost solely one of increased production. Fortunately, raw materials were accessible for the enormous increase required, and so much plant was built as to tax our productive capacity of electric energy and electrical equipment.

The aluminum production in the United States has been increased about seven-fold to nearly 1,200,000 tons a year; that in Canada also has been greatly expanded. Some of the Government-built plants were placed in high cost power areas because no large blocks of cheap power were available anywhere. The aluminum industry in the United States is based largely on the use of South American bauxite, although our domestic bauxites have supplied part of the requirements for aluminum, and for most of the alumina abrasives and aluminum chemicals. In anticipation of a long war and the possibility that sea lanes from the foreign bauxite deposits might be closed, early consideration was given to the development of processes to utilize siliceous bauxites, clay, and other domestic minerals as sources of alumina.

The production of aluminum oxide of the requisite high purity involves difficult chemical engineering, especially since the operation must be conducted on such a huge scale. For each ton of metal, two tons of oxide or four tons of bauxite are required. If clay, for example, were used instead of bauxite, about eight tons of clay would be necessary per ton of aluminum. Hence, in planning a major operation based on clay, it is essential that the extent as well as the purity of the deposit be well proved.

From the dozens of proposals for the utilization of domestic aluminous materials, several were selected for intensive investigation. This was done only after painstaking study of the technology, often in the laboratory and on pilot plant scale, and of the economics. As a result, several processes are now ready for exploitation on a semi-commercial scale. Should it become necessary for this country to supply its own raw materials it will be able to do so, even for a long war. Our own bauxites will supply our present needs for longer than the time required to build plants and transfer production to clay, alunite and similar raw materials. The reserves of domestic bauxites have been greatly increased by recent exploration and by the establishment of a successful process to recover alumina from "red mud" and siliceous bauxites containing as high as 15% silica.

The fact that processes have been approved for the production of alumina from clay does not mean that they will be used during this war or that they will prove to be economical after the war. In fact, so long as we can obtain bauxite at a reasonable cost, the reverse is true. It is estimated that the first cost of a clay plant would be from two to three times as much as a bauxite plant per unit of product, and the operating costs would be at least twice. Since cost today is measured largely in man-hours and materials, it is evident that to make aluminum from clay would represent a wasteful procedure in war as well as in peace, so long as good bauxite is accessible at a reasonable cost.

Various Processes for Magnesium

The development of our war-time industry has been even more phenomenal in magnesium. While the new plant capacity of nearly 300,000 tons a year is less than for aluminum, it represents an increase of nearly 100-fold, and is significant when compared with the pre-war aluminum production in this country (175,000 tons).

The major part of this expansion has been in plants using the fused-chloride electrolytic process. The magnesium chloride (electrolytic cell feed) comes from a variety of sources. The Dow plants in Michigan use natural brines; the Dow plants in Texas use sea water; the Diamond Alkali and Mathieson Alkali plants use by-product calcium chloride and dolomite; the International plant uses dolomite and a magnesium salt by-product from the extraction of potassium salts from a natural salt deposit; and the Basic plant in Nevada uses magnesite.

This enormous and rapid development taxed

the nation's capacity to produce electrical converters and other equipment, so much that a portion of the magnesium had to be made by some process other than the electrolytic. Notable among these is the Hansgirg process, which had been started in operation late in 1941, and is based on the reduction of magnesium from magnesium oxide by carbon in the electric furnace. The process was complicated due to the care required in handling finely powdered magnesium, and the need for re-distilling it to obtain the metal in compact form for subsequent melting. An alternative was one or more of the thermal processes used in England and on the Continent, based on reduction of magnesium oxide with either calcium carbide or aluminum metal. On study, they seemed to be too expensive. Decision was made therefore in December, 1941, to develop the ferrosilicon process, even though it was then still in the experimental stage. Successful small-scale operations had been conducted and important contributions to the process had already been made by Pidgeon, working at National Research Council in Ottawa, Canada.

Contracts were made early in 1942 with six U. S. companies to construct and operate this Pidgeon process in plants with a total annual capacity of 69,000 tons. And immediately a research project was organized at the New Jersey Zinc Co. by the War Metallurgy Committee, designed to improve the process and to spread "know-how" among the contracting organizations. As a result of this project and of the consequent excellent cooperation and contributions of the operating companies, the process has been constantly perfected and made to function excellently in an extremely short time.

The process depends on the reaction between calcined dolomite and ferrosilicon to produce magnesium metal in vapor form and a residue of calcium silicate. The charge in briquette form is externally heated under high vacuum to about 2150° F., usually in heat resistant tubes having a condenser welded on at one end where the magnesium metal solidifies into muff-shaped masses. The ferrosilicon process has proved to be a simple, fairly economical means for thermally producing magnesium from readily available raw materials in a plant that may be readily erected and placed into operation. For this reason, new production, were it required, would undoubtedly be made by this process.

The increased production of both magnesium and aluminum has been so successful that even now sufficient product is being made to provide for present production of aircraft and incendiaries, the primary consumers of these metals. Along with this phenomenal production record, the metallurgist and engineer have also established a record for new engineering application of these metals. Techniques have been improved to permit designers to take advantage of the high strength aluminum alloys; methods of forming, welding and fabrication have been vastly improved. More knowledge is being gained of the stronger magnesium-base alloys, and recently they have been used more widely as castings for aircraft as foundry techniques have improved.

Beryllium, whose future as a light metal was painted so glowingly by some enthusiast but two years ago, has found its real usefulness in another field. As a constructional metal or alloy, of value because of its high strength-weight ratio, it has not materialized. Difficulties in casting and forming the aluminum alloys of beryllium, its scarcity and high cost have combined to restrict its use to its established place as a strengthener of copper. For this purpose, beryllium has been in great demand. In fact, its use in copper alloys of high fatigue properties has taxed the limited supply of this metal.

Achievement by Free Cooperation

This chonicle of a few of the developments of the past three years in metals is a story of achievements by American science and industry. It is as much a report of "all-out cooperation" as it is of "all-out production". Science and industry, through the catalysis of Government, have united to create our gigantic metal producing machine. The vast stores of technical knowledge and operating "know-how" have been contributed to the common cause by industries, companies and individuals. It has been the function of the War Metallurgy Committee to aid in making this exchange of information possible. This Committee has worked in close cooperation with the War Production Board on most of the projects reviewed in this paper.

In this program the policy has been to recommend those procedures that were tried and proven whenever conditions afforded their use, rather than to embark upon untried and visionary proposals, even though they appeared to some to have great promise. Appraisal on the basis of cost of man-hours and strategic materials under a war economy is not unlike appraisal on the basis of cost in dollars in peacetime.

While this story has told mainly of this nation's present accomplishments in production and conservation, it incidentally points out that should importations cease or requirements for metals increase, America is prepared.

Some months ago The Editor was invited by the quasi-governmental Committee for Economic Development to prepare this chapter on Metals for a booklet designed to tell American manufacturers (in non-technical language) what they could expect of post-war materials

Metals in Post-War America

ANY REALISTIC CONSIDERATION of the foreseeable future uses of metals should be based on the fact that iron and its alloys known as steel are the metallic foundation of our material civilization, *and will continue to be*, despite the enthusiastic claims for organic substitutes. Iron and steel have attained that place by virtue of their low price and widespread availability, ease of working, and ability to take on a great variety of useful properties at the command of the melter, fabricator and heat treater.

Hundreds of subcontractors during the war have gained new knowledge about the working and heat treating of irons and steels — sometimes operations never before performed — so these factors will immediately promote the use of fine steels even more. One long-range retarding factor operating over the years will be that the real cost of iron in the United States is bound to increase, due to the rapid exhaustion of the "bonanza" deposits of high grade iron ore in the Lake Superior region, on which our unexampled iron and steel industry is largely based.

Probably the largest competition to steel will come, not from organic substances or from plastics, but from the light metals aluminum and magnesium. Both of these are comparatively new to industry — magnesium especially — and so we metallurgists are not so sure of their eventual capabilities. Aluminum was first produced by our modern process 50 years ago, but has been intensively studied and vigorously promoted, and has won consideration in any application where the object, tool, or machine part must move, stop and start, thus making lightness an energy-saver. Use of both aluminum and magnesium (especially of their hardenable alloys, of which there are a great number already known) is bound to increase in all the transportation industries — ships, railroads, automobiles, aircraft — as shortages in fuel become more pressing and price of energy rises. Hand tools and domestic machinery will utilize more and more of the light metals. The non-corrodibility and beauty of aluminum will favor its use in furniture, utensils and architecture. However, even though its price may be expected to be lowered somewhat, even below the present bargain level, this trend will be stopped by the lack of high grade ore in North America — the same factor that will make steel more costly. Our known reserves of good bauxite ore are modest, and while "aluminum from clay" is a good slogan, clay is an impure ore of aluminum and costly to work. More opportunity exists for cheaper magnesium because a ready source is truly inexhaustible in natural brines and in the ocean itself.

So American metal-using industry will face these opposing influences: Iron and steel from a 30% expanded industry whose costs are rising, competing with the light metals from a vastly overbuilt industry (aluminum 7-fold pre-war,

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magnesium 100-fold) whose selling prices will be driven down to narrow the wide gap formerly existing. Herein will probably arise the next decade's most intense competition between post-war metals. The other metals, common or rare, will doubtless be increasing in real costs, owing to the limited domestic ore supplies, and each will therefore be utilized primarily and nearly exclusively for its unique properties, well known to users. A more generous supply of metals like copper and zinc will await a settled policy of the American government concerning foreign trade — especially importations that might replace home production from dwindling resources. Some special metals will also have meteoric careers, but since their supply may be measured in ounces or pounds rather than in tons, they can hardly be mentioned in such a sketchy account as this attempts to be.

A more detailed consideration of several important metals will now be given:

Iron, the principal metal, is also one of our most ancient servants. We know, pretty well, its faults and its virtues — which is more than can be said for many of its Johnny-come-lately "substitutes". Iron is easy to cast; the iron foundries will retain their ability to make — at lowest costs — intricate shapes of moderately strong metal. By virtue of improved foundry practice and of alloying additions, the mechanical properties, machinability and durability of cast iron have been steadily improved since World War I. Even better "high strength" iron castings have been made during World War II; those who think that nothing but a steel casting is good enough may find that their competitors are using the new cast irons to better advantage. Of course, the steel foundries also have improved — witness their ability to cast a complete tank's armor in one piece, and of a rugged metal that formerly required the most special care in steel making, forging and heat treating. It is safe to say that the present-day foundry product can be so much superior to the old-fashioned gray iron, malleable iron, or cast steel, that its utility must be carefully appraised in any competitive design.[1]

Steel is primarily an alloy of iron with a little carbon, and is hardenable by heat treatment (quenching from a red heat). Progressively more carbon gives harder and harder steels. The low carbon steels (or mild steels with ¼% carbon or less) are used for plates, pipes, sheet, wire, structural shapes, and constitute by far the largest proportion of all steels. They are seldom heat treated, but doubtless one of the next advances in metallurgy will be the heat treatment of soft steel parts, in order to make the most of what you pay for. In the past few years their quality has generally been improved. Especially has the drawability and workability of sheet steel been bettered; intricate shapes can be pressed, combinations joined automatically by new welding, brazing or soldering processes, and so perform the duties once placed on forgings or castings. Structural steel and pipe is now so much better that all engineering applications may be redesigned for higher working stresses.

The high carbon steels, ranging around 1% carbon, are the basis of toolsteels. Especially when alloyed, a gamut of such steels enables the machinist to select the most efficient tool for cutlery, battering tools, lathe tools, fast finishing tools, roughing tools. Special non-ferrous alloys like "stellite" and the tungsten carbide tools like "carboloy" open up entirely new vistas in speedy and fine cutting, wire drawing, and other cold forging operations.[2] A revolutionary increase in cutting speed followed the introduction of the tungsten-chromium-vanadium "high speed" toolsteels about 40 years ago; we are on the verge of an even greater speed up in milling operations as we apply to steel the technique already developed for the light metals.

To return to steels: The alloy steels are also comparative youngsters in the metallurgical family. The first alloy steels were used, less than a century ago, for cutting tools; then armor and armor piercing projectiles utilized the advantages of nickel, chromium and vanadium. In the late 1890's some scrap armor was made into bicycle chain links — the first application of alloy steels to machinery parts. During World War I industry was called upon to make ordnance, yet with few exceptions American plants were woefully lacking in experience with alloy steels or the heat treatment of anything by anybody except simple tools by the toolsmith. World War I therefore spread out metallurgical information from the arsenals to industry, a movement that has gone forward vigorously. Enormous amounts of study have since been given to the influence of alloys on all metals, and the "Science of Metals" has been born — an event of untold importance to wide-awake industrialists.

Fortified with more exact knowledge about the function of alloying elements in steel, the mass production industries (automotive, house-

[1] American Foundrymen's Association, 222 West Adams St., Chicago, has issued valuable "Cast Metals Handbooks".

[2] A comprehensive view of the toolsteels is given in "Tool Steels" by J. P. Gill, R. S. Rose, G. A. Roberts, H. G. Johnstin and R. B. George, published by the American Society for Metals.

hold equipment, machine tools, business machines, agricultural machinery) have steadily fostered the change from the fool-proof but more expensive steels containing much alloy to the less expensive lower alloy steels. A saving of 0.1¢ per gear in alloy is worth while if you make 2,000,000 gears a year! This trend toward low alloy steels has been given added impetus during the present war. Guns, armor and projectiles demand much alloy, and little is left over for auxiliary machine parts. To eke out the dwindling supply, and to utilize to best advantage the alloying elements in the returning scrap, the National Emergency steels were formulated, which carry to the logical conclusions the 30-year trend toward low alloy engineering steels. Doubtless they are here to stay — at least several of them — for they are amply good enough for a multitude of purposes. Doubtless they will also be improved by the steel makers, for we have a three-fold expansion in electric furnace capacity to keep busy. These new electric furnaces were intended for the highest quality of ordnance material — for guns, armor, aircraft engines, and mechanical bearings — but already some of this capacity has been turned toward the production of carbon steels, and after the war will be ready to enhance even further, by best steel melting practice, the properties of these low alloy, National Emergency steels.[3]

A caution is in order: Brains and ability are needed to make proper application of substitutes. The "old reliable" is reliable largely because it is more or less fool-proof. Unless the organization is properly staffed with intelligent men, better stick to the "old reliable". However, in that case you had better expect that your more progressive competitors will do the working and worrying necessary to make a better product with more economical materials or methods.

Stainless Steels warrant a sub-head all of their own because they approach the noble metals in resistance to liquid corrosion by water, acids, chemicals, crude oils, and foodstuffs, as well as resistance to hot gases and molten metals. A numerous family of these alloys has grown up in the last 30 years, and the fundamental analyses are constantly being modified to suit new and specialized services. Comparatively large proportions of chromium and nickel are indispensable — sometimes iron is the minor metal. Even though intrinsically costly, modern manufacturing methods enabled even so cost-conscious an industry as the automotive to use great quantities of these steels for exterior trim in the pre-war era. They have already become quite indispensable to the heat treatment, petroleum, chemical, food, power and aviation industries.[4] Their utility will be bound to increase in post-war times, for no other substance (metallic or non-metallic) can match their unique combination of desirable properties.

Copper — The original uses of copper — a prehistoric metal — were for its permanence, its non-corrodibility in atmosphere and rain. While it is still valuable for exterior architectural applications, it now enjoys active competition from aluminum for all such purposes. Coated steel may also have long enough life. With the coming of the electrical age, copper came into its own for conductors, and in this it will doubtless remain pre-eminent. Nothing approaches pure copper's conductivity except silver, which is too costly. Aluminum does compete on a weight basis, and is widely used for conductors wherever its greater bulk can be tolerated. Copper is also the basis of two important families of alloys, brasses and bronzes, when alloyed with such metals as zinc and tin, and the brasses and bronzes have superior qualities of durability, beauty, and workability. Frequently the ready machinability or workability of a brass will warrant its use for a highly fabricated article like a screw, even though the raw material cost per pound may appear to be high.[5] Real costs of copper and copper alloys are bound to increase, since the tenor of America's copper and zinc ore deposits is rapidly lowering. We have mined out our bonanzas, and the cheapest copper is mined abroad. However, since the metal is practically indestructible by corrosion, a large amount is eventually recovered from scrap — before very long we will undoubtedly get more "new" copper from dis-used articles and demolitions than from "virgin" ore. The one is as good as the other — nobody can tell them apart.

Nickel is an important metal in its own right, in addition to its indispensable use as an alloy in steels, stainless steels, and cast irons. Practically the whole world's supply (90%) is mined in Canada, and its properties have been carefully

[3]The most complete and up-to-date description of National Emergency steels and their properties, workability, heat treatment and utility, is contained in a booklet issued by the American Society for Metals. Much of the original information on their development, properties and utility is in a series of publications by the American Iron & Steel Institute, 350 Fifth Ave., New York City, entitled "Contributions to the Metallurgy of Steel".

[4]See "The Book of Stainless Steels", published by American Society for Metals.

[5]See "Copper and Copper Base Alloys" by R. A. Wilkins and E. S. Bunn, published by McGraw-Hill Book Co., 330 W. 42nd St., New York City.

studied and vigorously promoted by the principal producer.[6] Nickel-copper brasses and bronzes and the "natural alloy" monel metal are especially valuable for difficult corrosion problems. Nickel-iron alloys have remarkable electrical, magnetic and thermal properties. High nickel alloys have great heat resistance. Finally nickel, the metal, makes a pleasing, durable electroplate.

Zinc was for long centuries principally used for alloying with copper to make the very useful brasses. More recently it became popular as a protective coating; iron and steel articles were dipped in molten zinc, and a thin surface layer was carried out. For this purpose zinc is fairly stable against most exposures, and is also "sacrificial", by that meaning that if the coating is penetrated by a corrosive solution the iron underneath is protected until the last of the zinc is dissolved. Unfortunately for the reputation of galvanized iron and steel during the last 20 years, the amount of zinc on "protected" articles has been reduced to such an extent that their life has suffered greatly, especially in industrial atmospheres. This of course is only an abberation of industry — the real value of zinc still remains, ready for all who are able to compute the real costs of an article. Electrolytic methods for coating zinc on wire and sheet have improved the uniformity of coating and its ductility, so "galvanized iron" is still very useful for many places where life of 10 to 20 years is all that is expected.

An important recent use of zinc (or rather, its strong, pure alloys) is for die castings. These are made by a process whereby molten metal is forced into a prepared cavity in a permanent steel mold; when the mold is open, the part is found to have a high degree of accuracy. Amazingly intricate and precise parts may be so made, requiring practically no finish machining. Intense study of casting methods and nature of alloy have improved the product so that even the U.S. Army Ordnance Department accepts die castings for essential and critical uses. "Precision casting" is the new word for it.

Die Castings, of course, are not limited to zinc alloys. Aluminum and brass, as well as lower-melting lead alloys, have large and increasing industrial uses.[7] They have shown the way for two relatively new materials made in substantially the same equipment — molded plastics and powder metals. Aluminum die castings will be artificially stimulated in the immediate years, because so much scrap metal will come back from wrecked or obsolete aircraft.

Powder Metals are the newest of all; they start with just that — metal particles fine as flour. Two or more metallic powders may be mixed, like copper and lead, and pressed in the form of a bearing. Or metal and non-metal powders may be mixed, like tungsten and carbon, to form a hard-cutting carbide. Or even a single metal like iron powder may be pressed into useful shapes. In manufacture, a properly mixed and sized powder is poured into a steel mold of proper shape, and squeezed in a powerful press. The compact that emerges is rather fragile, but its shape is as accurate as the steel mold, and it may be hardened by "sintering" (heating in a protective atmosphere to such a temperature that the particles alloy and join one with another at their points of contact). Parts may be re-struck in dies for greater accuracy and density.

Obviously the method is adaptable to reasonably small parts made in fairly large number. Up to the present, the greatest success has been for objects requiring properties difficult to get in any other way — for instance, bearings porous enough to suck up oil and be self-lubricating, or thimbles that filter fine solids from motor fuel, or welding electrodes or electrical contactors where hard tungsten and conductive copper are mixed (they cannot be alloyed by welding), or the compacting of almost infusible metals like platinum, tungsten, molybdenum and tantalum, or mixtures of metals and non-metals. Here is a great field for specialties — if you are stumped, call in a powder metal expert![8]

Tin — The United States has always been dependent on foreign mines and smelters for its pig tin, even though it has consumed more than 50% of the world's production. Most of this tin is produced in Eastern Asia and Malaya, and none has been coming from these regions since the Japanese army's occupation. During the past two years, in order to conserve our stocks and those subsequently obtained from new smelters working on Bolivian ores, and plants recovering tin from scrap bronzes and tin cans, it became necessary to limit all uses of new tin in bronzes, solders, and bearings, and develop a new process for the production of tinplate. This new electrolytic process requires just about one-third the amount of tin per ton of tinplate produced by the old hot dip process. Thus a new standard of manufacture has been developed which will undoubtedly continue after the war. What can be done or expected is measured by the achieve-

[6]International Nickel Co., Inc., 67 Wall St., New York City.

[7]Valuable publications may be secured from New Jersey Zinc Co., 160 Front St., New York City, and Aluminum Co. of America, Gulf Bldg., Pittsburgh.

[8]See "Powder Metallurgy", edited by John Wulff, published by American Society for Metals.

ments of the tin can manufacturers, who are using chemical coatings on the can-ends, electrolytic tinplate on the can-sides, and a lead-silver solder on the seams, thus reducing the amount of tin to one-fifth the pre-war requirement.

Solder and babbitt are the next largest consumers of tin, after tinplate. The percentages of tin in solder and babbitt mixtures have been materially reduced by War Production Board directives. For certain applications of solder the tin has been eliminated entirely by the substitution of a very small percentage of silver. Experience already gained in the use of wartime lead-silver solders and copper-lead babbitts has definitely established them as a post-war commodity for certain applications.

It results that America is now getting by satisfactorily with about one-third its peacetime supply of tin, even though war production is inflated to an unprecedented level. No doubt we will never again go back to the lavish use of this costly metal in many mass production items, even though from a political and lend-lease point of view it might be highly desirable to reestablish generous imports of Straits tin.

Lead is the one metal that has been in easiest supply during World War II, and has therefore been substituted in many places where necessity has mothered the application. Much of the American production comes as a by-product of ores worked for copper and zinc; another large proportion of our supply is imported from Mexico. Lead is an excellent metal for corrosion resistance; for example, it is better than stainless steels for withstanding sulphuric acid, and therefore is largely used by the chemical and allied industries. Storage batteries use lead for an analogous reason. Since lead is weak, its principal structural use is as a lining material. Lead coated steel is a wartime product of peacetime promise. New means have also been found to harden lead, with greatly increased production of tubing and water piping — such an ancient use as to give the name to the "plumber". Babbitt and many new types of bearing materials are really hardened leads. Lead, with a similar metal bismuth, is the basis of most fusible metals, safety devices and solders.

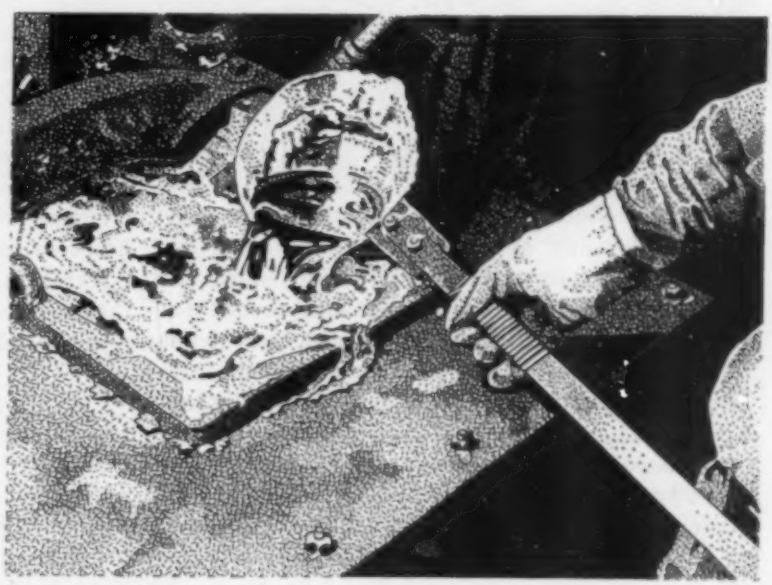
In viewing the metallurgical scene, do not forget this ancient metal; it has surprising capabilities.

The Light Metals are aluminum, magnesium and beryllium. Their importance has been magnified out of true perspective during recent years by the aircraft industry. A few words will first be said about the last mentioned.

Beryllium may almost be called a "political" metal. Since it is lighter than either aluminum or magnesium, it has been touted as a better metal. There are two blotches on this fair picture: First is that the minerals from which it can be reduced are exceedingly rare. Second is that the metal adopts a crystalline arrangement that is inherently brittle. In this it is like silicon, an exceedingly common metal or near-metal — also light. Ductile forms of either silicon or beryllium have so far eluded metallurgical investigation. Consequently the only present metallurgical use of beryllium (and silicon) is as an alloy. Copper with a little beryllium in it can be heat treated into remarkable hardness, and is widely used for springs, non-sparking tools, and many other uses where hard copper is desirable.

Aluminum is the most important light metal, and will be available to industry in great quantity — ore refining and ingot manufacturing capacity being expanded some seven-fold. Ingot price has been cut from 20¢ per lb. to 15¢. It has been intently studied and vigorously promoted for 50 years by the leading American producer, and its properties are so well known that they need not be repeated.[9] Numerous alloys are available; some specifically adapted for forging, extrusion, casting, or machining, as the case may be. Many of these alloys are heat treatable; that is, they stiffen and harden after quenching. The metal is silvery and pleasing in appearance; durable colored finishes can readily *(Cont. on page 126)*

[9]Pamphlets on all phases of aluminum fabrication and treatment are available from Aluminum Co. of America, Gulf Bldg., Pittsburgh.



This contribution to the Group Meeting on Non-Destructive Tests at the Chicago Convention contains such a broad survey of X-ray equipment, accessories, and applications of radiography, that it is a worthy addition to the group of reviews wherein it now finds itself

Recent Developments in X-Ray Inspection

X-RAY INSPECTION might profitably be divided into several fields for the purpose of describing the recent developments and their relation to the war effort, or of considering post-war possibilities. Such fields are: *(a)* X-ray equipment and accessories, *(b)* films and film processing, *(c)* X-ray interpretation, and *(d)* applications of radiography.

Perhaps the largest number of outstanding developments have occurred in X-ray equipment. They have resulted in much saving in time and expense, and also in improving the sensitivity of the method. These developments have been in the following types of apparatus: *(a)* Automatic fluoroscopes, *(b)* automatic radiographic units, and *(c)* high voltage (million volt) equipment.

Fluoroscope— Automatic fluoroscopic equipment is now able to inspect vital war products made of non-metallic materials at a rate of approximately 4000 parts per hour. In these devices the variation in the amount of X-ray energy transmitted through a sound part or one containing voids operates a suitable electronic circuit, the components of which mark the unsound part, initiate a signal and record the energy variation on a meter. A pilot part determined to be unserviceable is re-examined after every three parts to keep the operation in standardization.

Fluoroscopic X-ray equipment has always attracted the interest of the radiographer of metal castings because of the speed of operation and its elimination of the cost of film and time of processing. Generally, investigations of fluoroscopic equipment have resulted in nothing but discouragement because of the appreciably lower sensitivity and lack of penetration compared to the film method. However, fluoroscopes have been installed in some of the aluminum alloy die casting plants. Die castings have only been approved for non-stressed or low stressed aircraft applications until recently, when a new specification permitting die castings for critical parts appeared, which, among other safeguards, required a certain percentage of the castings to be X-rayed. The low density aluminum-silicon or aluminum-magnesium alloy die castings with relatively thin walls offered an ideal opportunity for the fluoroscopic method. New equipment capable of operating at higher milliamperes (20 to 30) in the range of 30 to 160 kv. has been introduced, as well as a new coated lead protecting glass having a much reduced refraction and consequent higher contrast and clearer vision. Protection consists of four thicknesses of lead glass, each containing a non-refracting film. A year ago a sensitivity of 10 to 15% was about the best that could be expected for aluminum alloy castings. The specially proc-

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essed lead glass for direct vision with the high voltage-current unit has reduced this range to 5 to 8% and under ideal conditions 3 to 5% sensitivities have been attained. Ingenious rotating fixtures and handling devices have increased the adaptability and reduced the time of complete examination. Another interesting fluoroscopic application has been the routine inspection of aluminum alloy aircraft landing wheels for large macroscopic shrinkage cavities in the gated areas.

It is certain that the future will see more improvements in fluoroscopic equipment and accessories which will undoubtedly expand the use of this quick and inexpensive method for the examination of light alloy castings.

Automatic Equipment has also been developed for the continuous radiographic inspection of numerous small aluminum, magnesium and steel aircraft castings. Former X-ray units operated intermittently, with off-time necessary to remove the group of exposed castings from the X-ray table and arrange the next group to be inspected. In the new continuous apparatus, the X-ray tube or tubes are completely encased in lead housings which, during the exposure, fit into a protecting lead flange on the positioning table. Personnel can be in the exposure room at all times arranging or disassembling, and in this manner parts can flow continuously through the room. As many as 17,000 parts per 8-hr. day have been examined by a unit of this design with an enormous saving in man-hours and cost, as compared with a unit operated intermittently. It is predicted that the use of this type of equipment will expand where it is necessary to inspect sub-surface conditions in large numbers of similar small parts.

Automatic Unit for Measuring Powder in Hand Grenade Fuses, to Prevent Duds or Prematures, at Rate of 4000 per Hr. Courtesy G. E. X-Ray Corp.

The radiographer of aluminum and magnesium alloy castings and spot welds has received attention by the extension of the range of the 140 to 150-kv. transformers to voltages as low as 30 kv. The focal spots of X-ray tubes for this type of apparatus have been appreciably decreased and the tube current capacity increased. These developments have, of course, improved the sensitivity and detail of the radiographs. However, the consumer of both light alloy and steel or bronze castings with medium sections has not been so fortunate, and is forced to purchase several units to cover the range whether his production justifies the expense or not. Perhaps an all-purpose flexible unit having a tube with fine focal spot, operating from 30 to 220-kv. (with 20 ma. possible in the 30 to 80-kv. range) will be a future development.

Million-Volt Apparatus — The major and very significant development in the inspection of welded steel pressure vessels has been the introduction of 1000-kv. apparatus. In 1932 the existing 200-kv. units could penetrate about 3 in. of steel in about an hour. The demand for greater penetration was ably met by the development of 300, then 400, then 500 and now 1000-kv. apparatus. Research work is still being conducted on super-voltage X-rays produced by the magnetic induction acceleration of the electrons to speeds equivalent to voltages between 1000 and 100,000 kv., and information should soon be available as to the maximum voltage for practical industrial applications. The 1000-kv. unit has enabled the following changes to be made in the radiographic examination of welded steel plates (according to Otis R. Carpenter of the Babcock and Wilcox Co.):

1. Eliminated the necessity of the Bucky grid formerly employed to reduce secondary radiation.
2. Eliminated the use of calcium tungstate intensifying screens and the accompanying graininess.
3. Because of items No. 1 and 2, has increased

many times the sensitivity of the X-ray method for the inspection of welded steel plates over 2 in. thick.

4. Reduced the exposure time from hours to minutes for heavy plates.

5. Made it possible to determine the relationship between voltage and steel plate thickness, thereby resulting in the standardization of technique so necessary for the inexperienced personnel that must now be employed.

Thus the best previous technique about 2 years ago for the examination of a 4-in. steel plate with a 400-kv. unit, Bucky grid, and calcium tungstate screens required a 3-hr. exposure, whereas now a 1000-kv. exposure with lead screens and the new fine-grain, high-contrast film produces a higher quality radiograph in 5 min.! The advantage of the high voltage increases with the thickness to be penetrated, although the voltage range should not be extended higher than necessary. For example, 400-kv. X-rays will produce radiographs with higher contrast and sensitivity than will 1000-kv. X-rays for steel plates 1¾ to 2¼ in. thick.*

The introduction of 1000-kv. apparatus for the inspection of heavy steel castings has also produced very beneficial results, according to D. M. McCutcheon of Ford Motor Co. It is possible to penetrate a large number of steel castings in a single exposure because of the spherical beam radiation and the high voltage. Here again, the high voltage, lead screen, fine-grain film technique produces a higher quality radiograph than the older single exposure low-voltage technique with intensifying screens. This new technique has improved radiographs of castings varying in wall thickness, containing round sections, or parts of the casting located at some distance from the film during the exposure. It has even been possible to penetrate 11½ in. of steel in 60 min. with a 24-in. focal distance, 0.045-in. lead filter and non-screen film.

Technician Sets up 1,000,000-Volt X-Ray to Examine 6-In. Wall of Steel Turbine Casting. Courtesy General Electric Co.

Film Processing — The continuously expanding applications of radiography have incited improvements in film developing solutions in the direction of higher contrast, convenience or reduction of time in preparing solutions, and greater activity. The most significant was the introduction of liquid developers requiring only dilution with water, equivalent in contrast and life to the former powdered substances. Liquid replenishers have added another convenience to the dark room, enabling the technician to maintain the strength of the solutions throughout the life of the developer. He also has some choice in the manner in which he compounds the liquid developer, so that he may select a developer having the best life and lower activity, or one giving a development time of 3 min.

*See also "Ten Years' Progress in Radiography" by A. J. Moses, *Metal Progress*, November 1941, page 771.

(instead of 5 at 68° F.) but having lower stability. The lower stability is not a disadvantage in a busy dark room where the developer rapidly expends its chemical activity. Film fixing chemicals are also available in liquid form with a life comparable to the powdered ones.

Automatic developing units have considerably increased processing efficiency in laboratories where large numbers of films are handled. Films placed in double hangers are developed, stopped, rinsed, fixed, washed, and dried rapidly in infra-red or hot-air driers — all without the touch of a human hand. Agitation is also provided in the developing and fixing tanks. As many as 170 films 14 by 17 in. (or 280 of the 7 by 24-in. size) have been processed in an hour by units of this nature. (A brief description of such a mechanized unit is in The Editor's "Critical Points" for October 1941, page 669.)

Screens — In spite of the fact that the quality, flexibility and speed of intensifying screens have been constantly improved, such screens are relatively unimportant today. Calcium tungstate screens were formerly used only to a limited extent for light alloy radiography, but extensively for reducing exposure time in the inspection of heavy steel castings and welded plates. The introduction of higher voltage equipment and faster, direct exposure type films has made it possible, with good economy and increased sensitivity, to perform much of the work on heavy steel without intensifying screens. The trend is definitely away from their use.

Although their properties have been known for some time, lead foil screens have recently become popular. These screens have some intensifying action, but primarily reduce secondary radiation and thereby improve the quality and latitude of the radiograph. Their utility is indicated in such operations as for radiography of miscellaneous castings of light alloys, castings of round or irregular shape of all metals, and for practically all work with high voltage or gamma rays.

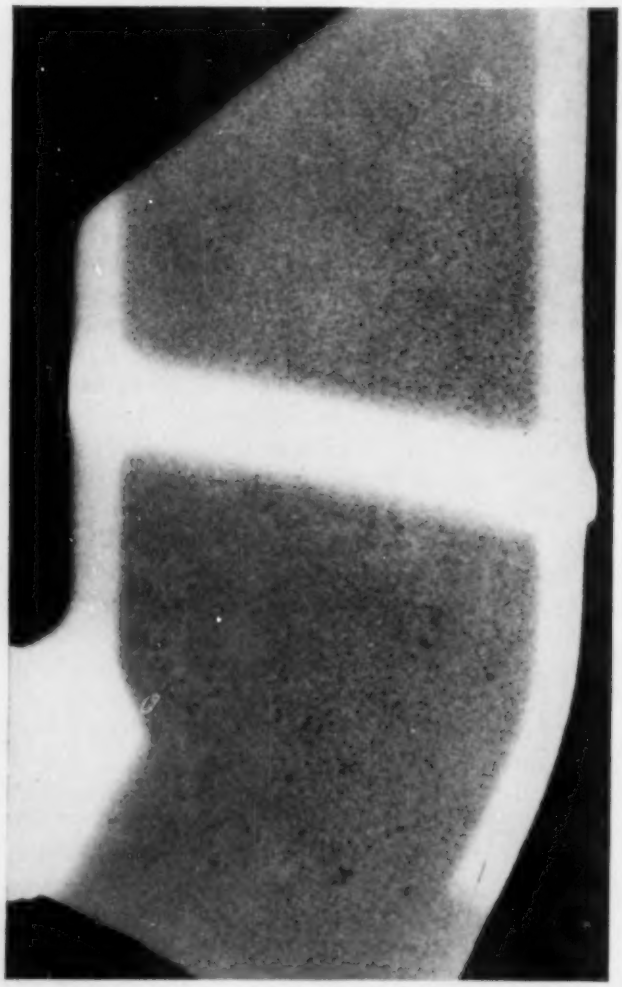
Film — For some years, the screen and direct exposure types of films used in medical radiography were the only ones available to the industrial laboratory. Radiographic inspection of light alloy aircraft castings demanded improvements in film if better detail were to be secured. As a result fine-grain, high-contrast films were put on the market and met with an enthusiastic reception. The new films vary in grain size, the finer the grain the slower the emulsion. The finest grain (slowest) is used where it is desired to magnify the radiograph — for example spot welds of sheet — while the faster film of this type is used for inspecting castings. Since the grain appearance of a film increases with the hardness of the radiation (higher voltages), these fine-grained films also instantly supplanted the earlier types for exposure to extremely high voltages. In fact this film has been as significant an advancement in the radiographic examination of heavy welded boiler drums and pressure vessels as has been the million-volt machine itself. Nothing but a brilliant future can be predicted for these films.

It should be apparent from the discussion of films, screens, and chemicals that, while there have been no radical changes in materials, the improvements have brought about substantial gains in quality and time saving.

It has long been recognized that the degree of contrast increases with the darkening of the film. A few years ago average sections were exposed to a H.D. (Hurtel and Driffield) darkening of 0.7 to 1.0. The increase in the threshhold value of the emulsions and the insistence on darker films by the Army Air Corps has caused many laboratories to step up the film densities to the range of 2.0 to 3.0 H.D. Unfortunately this trend has not been accompanied by improvements in film viewing equipment. It has sometimes been necessary for the interpreter to use two or three sources of illumination of different intensities in order to examine a single radiograph. Also much film has been over-heated and eyes imperiled by unprotected photo-flood bulbs. A compact illuminator having a variable resistance in series with a source of illumination that would permit the examination of films with densities ranging from 0.7 to 3.0 H.D. is needed immediately. It is also necessary for the illuminator to be equipped with suitable slides to mask

various areas, adequate cooling devices to prevent the over-heating of film and also a convenient means of replacing bulbs or tubes.

Industrial Applications — The time-tested applications of radiography for the routine inspection of boiler drums, pressure vessels, and other important weldments, the examination of castings to aid in the development of proper gating or casting practices, have continued to



"Go" and "No-Go" Radiographs, Coordinated With Structural Breakdown Tests, Have Widened the Utility of Light Metal Castings in Important Duties

expand enormously during the present emergency. However, the inspection of aircraft castings to comply with governmental specifications has caused the greatest single expansion of radiographic facilities that the metal industry has ever experienced. Undoubtedly, in the early stages thousands of serviceable castings were rejected because of arbitrary standards based on a doubtful radiographic appearance, or the extreme caution of many interpreters.

However, the insistence of the Air Corps for a correlation between radiographic appearance of a casting and tests approximating service conditions has done much to clarify this chaotic condition. Structural breakdown tests of aluminum castings as a unit by the laboratories of the Aluminum Co. of America have indicated that the average loads causing failure are four to five times the design load, where a material factor of two is applied. Thus some leniency is permissible in interpreting the significance of the discontinuities that may occur in such castings.

The immediate reaction to these findings is that castings can be used for much higher stressed parts than are conceived at the present time — or the various sections of the present castings could be reduced, thereby saving appreciable weight. The latter direction is restricted by practical considerations, because in many cases the foundry is now casting sections about as thin as possible. It would therefore be predicted that much of the routine X-ray inspection of aircraft castings of the present designs will be replaced by X-ray foundry control, and that the future use of mass X-ray inspection will be for castings subject to appreciably higher stresses than the present ones. Castings of this type should receive 100% X-ray inspection rather than a percentage. Of course the cost of such castings and the 100% X-ray inspection will have to be less than that of a suitable forging to survive the competition. It would seem, therefore, that the sound position for the X-ray inspection of aircraft castings would be the 100% examination of highly stressed castings. For castings of less importance the X-ray's proper use is for developing proper foundry practice, in conjunction with other methods of quality control.

Increased recognition of welding as a method of finishing, repairing, and salvaging castings has resulted in a greater application of radiography in foundries. Production demands have expanded the use of welding for repairing and salvaging castings containing small foundry defects. X-ray inspection of such repairs, particularly if made in the more highly stressed sections of castings, is often a recognized requirement and is doing much to insure the confidence of the customer in this method of repair and the satisfactory service of castings so repaired. Many of the aluminum and magnesium casting specifications today include well defined procedures for making such welds, as well as for their X-ray inspection. The welding of light alloy castings has considerably accelerated the demand for flexible low voltage X-ray apparatus, and it would seem that this new application of radiography is in only the beginning stages.

Mr. Vanick has been much in demand by ⊕ Chapters for his talks on foundry metallurgy, and at The Editor's request prepared this summary of his discourse. The author modestly appraises it as a review of metallurgy rather than of foundry practice

Trends in Iron Foundry Metallurgy

During the course of the war, emphasis on conservation led to significant changes in practice for melting and handling cast iron. One of the principal events was the briquetting of cast iron borings and steel turnings from machine shops, and turning these products back to the cupola for remelting. The procedure carried with it the need to recover the oil in these particles, partly to eliminate the smoke nuisance which accompanied their use in the cupola, and further to improve control over melting practice and, in turn, over metal quality.

Additional installations of hot blast systems have applied the conservation principle to the saving of coke. Recent work by Eash, described before the American Foundrymen's Association in 1941, which confirms the value of the hot blast in conserving 20 to 25% of coke, and the extensive work done by Vial (in *The Iron Age*, as early as Oct. 20, 1927, page 1071) in applying the hot blast principle, is being more widely studied. It is of course apparent that a 20% saving may be an insignificant achievement in shops melting less than 20 tons of iron per day, because the value of the coke saved is clear out of proportion to the cost of installing and maintaining the heat conserving systems. The space required for these installations often adds an additional obstacle. Future developments may improve the efficiency of these systems, reduce their bulk, and thus provide an appeal to save fuel in foundries of smaller tonnage.

In some shops the heat which the hot blast might have conserved in an economy sense is plowed back into the product to provide higher melting and operating temperatures in the cupola, with the resultant production of hotter iron at the spout. In general, hot metal and fast handling leads to sounder castings, accompanied by better physical properties in the metal. The need for hotter iron as a prerequisite for good physical properties, as well as sound castings, has been cogently pointed out by Timmins and Crosby (*Transactions*, A.F.A., 1941). Other factors contributing to future progress in this line are improvements in the fuel, higher coke beds, taller, more efficient cupola stacks, greater blast volumes, faster metal handling, insulated and covered mixing and transfer ladles, and similar details in melting and handling that conserve the heat that has been generated.

More and more installations of humidifying systems are controlling changes in weather which affect the air blast. Eash (*Transactions* A.F.A., 1941) reports some careful work on the humidity of the blast, concluding that when the composition of the product goes "off the beam" because of humidity conditions, the physical properties are altered directly in proportion to departures in composition. Foundrymen are becoming more conscious of the fact that variations in this raw material, air, which is so freely available, may affect the properties of the metallic product. Since a ton of air is blown in the cupola for each two tons of iron melted, some 10 to 20 quarts of water may go along with it to be burned and in turn take a toll of heat units out of the fuel bed and the metal charge. If the changes in weather could be anticipated sufficiently in advance, and

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compensating additions made to the cupola in the form of coke or silicon and manganese to balance the losses in carbon and silicon and manganese that wet blast will produce, a greater uniformity in the end product should result, but since weather changes may occur at intervals during the course of a single heat, it is obviously easier to add a mechanical or chemical system of control over the humidity of the blast. (Where castings vary in size, shape, section and quantity, finer control of the metallurgy of the product may be applied through additions to the hot metal at the cupola spout.) Where a humidity controlled blast system is installed, it might be possible to recover some of its cost through the reduced losses in carbon, silicon and manganese which should accompany its use.

These refinements in control, by humidifying and preheating units, point toward finer adjustment and more economical operation of the cupola. The work of Reese (published in *Transactions* of the A.F.A., 1938) in promoting care in the weighing, sizing and selection of raw materials, and providing a reserve of blast capacity adequate to increase production or improve operating details, represents points that might escape ordinary observation. Massari's review of world literature in the same publication in 1941 discloses the importance of these details and re-emphasizes their significance. The details of cupola operation, of charging stock and of handling metal at the spout and in the ladle, are important trifles which, when added up, lead to such substantial improvements that the practice is often called a "new process". The rapid application of these details indicates that the gray iron foundry industry will, in general, be operating at new high standards.

Duplex Melting

Some progress can be expected in the refinement of cast iron in auxiliary melting units. Cast iron production, as a rule, consists of a melting and mixing metallurgy, rather than one involving much chemical refinement of the product. The restricted availability of high grade charging stock has often forced the use of desulphurizers and other purifying fluxes. In the post-war period, some of these difficulties may be eliminated simply through the selection of better raw materials as these become available. In other cases, duplexing with an electric furnace may be indicated, wherever the production and quality required are great enough to justify the installation of the necessary auxiliary melting equipment. The sum of many improvements may be exemplified in the term "cast iron crankshaft type of metallurgy", requiring close control over the cast metal and adjustments to its composition as castings vary in weight and section. Such improved metallurgy will lead to the increasing use of electric furnaces as hot metal receivers, in which some refinement of the metal is possible, and wherein final adjustments in composition prior to pouring may be made (following a quick preliminary analysis and chill test). These duplexing practices will require closer weighing and measuring devices for controlling furnace and ladle contents.

The inoculation of cast iron, described over ten years ago by Coyle before the American Foundrymen's Association (1929), in which ladle additions of nickel and silicon had been used, has become more popular, and during the past several years its value has become better known. Bolton, Schneidewind, Boyles, and others have contributed much to the study of the origin and development of the graphite flake in cast irons, but a brilliant piece of work by Eash, reported before the A.F.A. in 1941, traces the mechanism of the birth and growth of graphite flakes after inoculation from their visible appearance to their final desirable form. The origin of the graphitizing reaction during the solidification of cast iron has been traced to a priming or pre-ignition of the reaction. Certain elements that promote graphitization at temperatures approaching the solidification range accelerate the reaction. Work upon this subject is still a long way from finished. The importance of a desirable form of graphite to resist seizing, galling and wear in cast iron is associated with these results which have been emphasized in the work published by Dost (A.S.M.E., 1940), E. K. Smith (A.F.A., 1940), Paul Lane (A.F.A., 1937), and others.

The use of inoculants tends to eliminate irregularities in the structure of cast iron, and in turn to produce a narrower range of physical properties, practically all of them improved in a desirable direction. For example, an iron that suffers from superheating or supercooling, or related effects, can be made to possess better strength, toughness, impact resistance, wear resistance, machinability, lesser chill, corrosion and heat resistance. Inoculants containing nickel, chromium, manganese, titanium and zirconium are commercially available and their use is steadily increasing as their functions become better known. Whether the inoculant contains alloys or is accompanied by alloy additions, the improvements are increased in proportion to the influence of the alloy on each property. During a recent survey of the application of cast iron at elevated

temperatures, it was found that 40% of the castings made for this exacting service had been treated by the inoculation process.

Along with these trends in foundry practice, there is a distinct progress toward simplification as represented by standardization of charging stock both in composition, size and quality. Alloying procedures have also been simplified and are moving toward standardization. These, in turn, lead to uniformity in quality. The foundryman can today produce the entire range of A.S.T.M. strength specifications from a single base mixture of iron — quite desirable where small quantities of irons differing in strength values are needed. Where the volume of production is large, it will be preferable, as in the past, to provide base mixtures which are best suited for the volume of castings to be made, and thus incorporate in addition to the necessary strength, such desirable related properties as machinability, heat resistance, wear resistance or toughness.

A milestone in progress appeared when the A.F.A. and the A.S.T.M. issued a chart classifying the type and size of graphite flakes in cast iron. This chart is not a specification, but it should save millions of words, oral and in print, that have been used to describe graphite flakes.

One important contribution to the development of high strength iron has been presented in Roth's description of the commercial production of 60,000-psi. iron before the American Foundrymen's Association in 1939. Progress continues in this type of product and the availability of a wider range of high-strength iron emphasizes the progress of this achievement. Reese and Flinn (A.F.A., 1941) have charted the course needed for the cupola production of cast irons possessing tensile strengths up to 100,000 psi.! These are alloyed with nickel and molybdenum, inoculated, and carefully processed to incorporate all of the finest features in the control of the cupola and handling of the metal.

The heat treatment of cast iron has kept pace with its progress elsewhere. In general, the high strength producible in the as-cast condition has eliminated the need for heat treating for high strength, with attendant difficulties with distortion. However, the 100,000 psi. iron may require a 600° F. anneal for 5 to 20 hr. to develop maximum strength. As interest in its production increases, some attention will be needed to provide for its proper heat treatment. For most commercial applications at present, cast irons are heat treated primarily to develop a high hardness so as to resist wear or abrasion.

Improvement in the properties of cast irons through heat treatment has been accompanied by some progress in methods and technique. For example, Bartholomew (*The Iron Age*, 1940) emphasized the marked improvement in wear resistance achieved by hot quenching certain alloyed cast irons. Buckingham (A.S.M.E., 1943 preprint) describes the greater load which the surfaces of gear teeth, cams, and rollers can carry before failing by pitting in the manner described as "surface fatigue". The application of flame hardening to lathe beds, as described by P. A. Abe in *Metal Progress* for July 1939, and the extension of this feature to alloy rolls by the Farrel-Birmingham Co. (*Machine Design*, August, 1940) indicates the trend in this direction. Application of induction heating to the hardening of cylinder liners, as practiced by the Caterpillar Tractor Co. (*Metals & Alloys*, June, 1941) marks a procedure which shows promise of being extended wherever quantities are processed in sufficient numbers to warrant the installation of the necessary devices.

In reviewing these developments of the past several years, one cannot escape the observation that there are some new ideas whose growth in industry has been stunted by more urgent production problems, while others have survived the test of time and continue to show a definite and progressive trend.

Pouring a Large Iron Casting at The Lunkenheimer Co.'s Foundry in Cincinnati

This paper was presented at one of the ASM Round Table discussions at the Chicago convention, but it comprises a forward-looking review of an important branch of metallurgy, so it is presented with others of the same tenor. Mr. Norwood predicts much more attention to the fabricating characteristics of alloys known to possess suitable mechanical, physical and chemical properties

Future Trends in High Alloy Steels

IN THIS DISCUSSION "high alloy steels" include all steels containing about 4% or over of alloying elements as well as those special heat resistant and corrosion resistant alloys which contain a substantial percentage of iron.

Compositions — The high alloy steels were fairly well developed during the last several years, but no one all-purpose composition has been found. The basic compositions will probably remain pretty much as they are now for some time, but we will undoubtedly modify these basic compositions considerably in a way which will permit a wider field of application. For example, there have been two widely used compositions in the stainless steel group — the 18% chromium, 8% nickel; and the 18% chromium, 10% nickel type containing molybdenum. The 18-8 type was successfully modified with columbium and titanium to stabilize the austenitic microstructure, while but little progress was made until recently in stabilizing the 18-10-Mo type with columbium due to the necessity of working out the proper balance of the various elements to ensure a stable structure without the presence of undesirable constituents. This work has already been reported in papers before the ASM — for example, in a paper by Messrs. Franks, Binder and Bishop before the 1940 convention. Experience with several commercial applications made during the past few years has been favorable and further developments extending the usefulness of the present standard compositions are confidently anticipated.

The alloy conservation program under which we are now working has shown that in certain instances the leaner alloy steels are quite satisfactory for applications where much richer alloy steels had previously been used. This has been particularly true where the service has required both resistance to oxidation and good mechanical properties at high temperatures.

It is believed, too, that the general trend for the corrosion resistant steels will be to return to the compositions which were standard before the war. The alloy steels designed primarily for corrosion resistance will probably lean toward types as high in alloying constituents as is consistent with good fabricating qualities. In the instances where both qualities cannot be obtained, the trend will be toward the newer methods of construction, involving precision casting and the newer methods of welding.

Alloys for Corrosion Resistance — The steels designed primarily for corrosion resistance will undoubtedly be made as foolproof as possible, since they generally have to possess good physical characteristics and fabricating qualities together with corrosion resistance. We will probably see extended use for those compositions which carry a stabilizing element to offset any damage which may be incurred during fabrication to their anti-corrosion properties, and in many instances these standard alloys will be further fortified so as to broaden their fields of application in regard to both mechanical and physical properties.

The elements normally considered essential in these alloy steels are chromium, nickel, molybdenum, manganese, columbium, and titanium. As already noted, future developments will pay greater attention to fabricating problems, and this will make it necessary to consider other constituents or elements present in relatively

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small quantities. Such useful minor constituents are nitrogen and carbon. Perhaps other elements present as impurities will receive equal attention, as they are known to exert a powerful effect upon the fabricating qualities. The austenitic types of stainless steel usually contain chromium and nickel in proportions which provide a stable microstructure. There have been many instances where it is desirable to have an austenitic alloy with smaller or greater amounts of one of these alloying elements, and use is made of nitrogen and manganese to keep the proper balance of constituents. Nitrogen aids in maintaining a stable austenite as does the manganese, but the main purpose of the latter is to provide good hot ductility. Considerable has been published on this subject in the past few years, but the real development along these lines is yet to come.

With few exceptions the progressive changes in analysis have so far been due to scarcity of one or more of the elements; future developments will look more to the benefits to be derived in the field of application. As an example, a high chromium alloy of the 25% chromium, 12% nickel type is desirable for most high temperature operation but the nickel has an undesirable catalytic effect upon certain processes. For such installations the nickel can be reduced considerably and its function as an austenite-former can be assumed by a suitable nitrogen addition.

The alloy steels of the stainless type will undoubtedly predominate in the future, as they have in the past, where corroding media of the oxidizing type are encountered. Improvements in the methods of fabrication and production as well as composition will extend the fields for the present types of corrosion resistant, high alloy steels. Also, the high alloys designed for resisting media of the reducing type, and such solutions as hydrochloric, phosphoric, and sulphuric acids, will find much more use due to the improvements being made in their fabricating qualities. It can be said, too, that the chromium-nickel-iron stainless alloys can be modified somewhat so that they are more resistant to the mildly reducing conditions. In general, it is the chromium content which gives resistance to the *oxidizing* corrodents, while nickel, molybdenum, copper, and sometimes manganese, are added to the alloys for resisting corrodents of the *reducing* type. An important phase in the future development of the already known high alloy compositions will be in the balancing of the alloying constituents to provide a stable structure.

Structural Alloys and Uses — The greatest development in the near future will probably be with the high alloy steels of the heat resisting type, particularly those which are not only resistant to deterioration at elevated temperatures but which have mechanical properties surpassing anything we have had in the past insofar as stress rupture and creep resistance are concerned. In this field a great deal of progress has been made, and we will see further tremendous advances in the near future in the field where high creep strength or stress rupture values at high temperatures are important, as in the development of power units such as the gas turbine.

The use of high alloy steels for structural purposes will increase considerably as a result of experiences gained in the past few years. They have both corrosion resistance and excellent mechanical properties. This permits the use of lighter sections, since allowance does not have to be made for corrosion and full advantage can be taken of the high strength-weight ratios. The chemical composition of the austenitic stainless steels has an important influence on their yield strengths, and the other mechanical properties developed by cold rolling.

Austenitic steels containing about 16% manganese have recently been introduced. A considerable amount of literature — especially Russian — is available. These steels develop excellent mechanical properties of about the same order as those obtained with the 18-8 chromium-nickel steels when cold worked. They can be readily fabricated by conventional methods and, while their resistance to corrosion is by no means as good as that of the chromium-nickel austenitic stainless steels, it is believed that it is ample for many structural applications. Like the other austenitic steels, they have excellent low temperature impact properties. Some such steels containing about 3% chromium have a fair resistance to progressive atmospheric corrosion. When they contain 12% chromium, the corrosion resistance approaches that of 18-8 chromium-nickel steel.

One factor which has been largely overlooked in the past but which has been demonstrated very thoroughly in many applications is the low upkeep of structures built of the high strength, high alloy steels. For this reason if for no other the use of the high alloy steels will probably be developed to a greater extent than ever — not only in the structural field for lightweight mobile structures, but also in such fields as food and beverage handling equipment. These uses already exist, and the war has brought out very forcibly the value of the stainless steels for such purposes.

Improvements made in the technique of ferro-alloy production — alloys to go into these high alloy steels — will also enable the industry to keep pace with the expanding demand for them.

This department, "Bits and Pieces", welcomes notes concerning new ways of doing things to metals, either in shop or laboratory. An ⊜ book of your choosing (other than the Metals Handbook) is the reward for a publishable item

Bits and Pieces

Metallurgicus' Own Pages

Pressure Quenching

LAST MONTH'S dissertation by METALLURGICUS on his own page went briefly into the subject of Die Quenching (although the Editor forgot to put a title on the item). Closely allied is the use of pressure (the same as high turbulence) in the quenching medium, without holding the work to be quenched in dies.

Attention was given to the advantages of thoroughly quenching steel parts in a discussion entitled "Quench Out" (*Metal Progress* for July 1943). Reference was then made to an earlier article by S. K. Oliver which showed the improved straightness of shafts resulting from a better quench. In his work, long slender shafts were uniformly hardened by dropping them into a long vertical tube up which the coolant was forced at a high rate of flow. This necessitated of course some provision for removing the pieces from the bottom of the pipe, but a trap door took care of that.

An alternative procedure accomplishing the same result is to hang the piece in a region of strong but well directed agitation of coolant. Violent movement alone is not enough, as Herbert French showed 15 years ago; "shadows" were found on the back side of cylinders quenched in a strong stream of coolant going in one direction only. The coolant must strike all surfaces simultaneously and symmetrically if distortion is to be minimized. See also the Editor's "Critical Points" for October, where he describes briefly the manufacture of long punches used in cartridge manufacture, and says the scheme that results in minimum warpage is to lower the punch vertically through a short inductor heater, ring shaped, immediately followed by jets from another ring shaped spray fixture, rotating the punch continuously so variations in the quenching spray are equalized.

Following this general principle, shafts may be nicely quenched by hanging them in the oil tank in the center of four or six vertical pipes, holes in which deliver streams of oil directed at the shaft. The easiest way to build such a rig is simply to have four pipes as long as the piece to be quenched, with ⅛-in. holes every ½ in. along one side of each, and arrange them 90° apart on a circle about 3 in. larger in diameter than the piece to be quenched, with holes pointed inward. When oil is supplied to the pipes under good pressure, an intense and uniform quenching zone is produced. This is an excellent way of quenching shafts, pins, broaches, and other long, straight pieces. Modification may be desirable; for example, rectangular pieces may be hung between parallel and opposed oil jets. Large gridirons of perforated pipes are traditional quenching devices for heavy armor plate.

Another way of quenching such parts that has been used in many plants is to equip the tank with a series of tubes whose diameter is ½ in. larger than the parts, and under the bottom of each tube provide an oil jet which will not only provide upward movement itself but will also inspirate oil from the tank and produce a strong upward current. Parts are simply hung in the tubes and removed when quenching is completed. This method has been successfully used for the quenching of stands of gears, rollers, and the like, after furnace heating or carburizing.

Often parts may be spun to advantage; in

one of Lindberg's excellent movies on "Heat Treating Hints", the spin-quench of long slender shafts was shown, and this has also been described in the published "Hints"; the shaft is simply rotated at a high rate of speed while it is lowered into the quench. Several years ago the same company offered a horizontal spinner quench of a special sort in which the round piece to be hardened was laid on two rolls (like a washing-machine wringer) and a third, driven roller was brought down on top as the whole rig was lowered into the quench tank. Crankshafts and long axles have been similarly handled in many plants; pressure from the third roll converts the fixture into a quenching die.

It is often helpful to bear in mind that the "good" part of the cooling cycle only has to last a short time, because the quality of the ultimate result is determined by the first few seconds — at least in shallow hardening steels, which is the variety for which pressure quenching is principally useful. Thus a piece may be quenched in submerged spray for half a minute to bring it "below the nose of the S-curve", then just hung in the tank or placed on a conveyor to cool as it will. Recognition of this fact may reduce the amount of quenching equipment required for a given output.

Perhaps the reader may think that undue emphasis is being placed on the quenching end of the heat treating process — but the heat treater or plant metallurgist of long experience has learned that "when there's hardening trouble, look first at the quench". This cannot be too strongly asserted; the difference between a good and a bad heat treating department is often largely in the quenching procedure. There are good and bad furnaces, of course, but the furnace is not usually at fault; with modern grain-growth-controlled steels the temperature for hardening need usually not be too rigorously held — but the *quench*, that's the thing!

Atmosphere controlled furnaces have sometimes been purchased to get away from scale in heat treating because the scale interfered with full quenching, when a little study of the quenching process itself would have rectified the trouble.

METALLURGICUS

Wanted: Model Suggestions

AN EXPERIENCED CARTOGRAPHER would find no difficulty in looking at a contour map and visualizing the peaks and valleys represented. Not all metallurgists possess this skill, which would be useful in visualizing the peaks and valleys of the temperature surface ordinarily represented by contours through various compositions of ternary systems. A solid model showing this surface would be useful in supplementing the data in the usual form. A little preliminary correspondence with those who have made such models indicates that several methods have been used, and suggests that there may be other model makers who could give useful hints on construction if the interest were brought to their attention. (FRANK G. NORRIS, Asst. Metallurgical Engineer, Wheeling Steel Corp.)

Early Detection of Fatigue Cracks

WE NOTED the method of determining fatigue cracks in test specimens outlined by Gerard H. Boss in the July issue of *Metal Progress*. He wipes the specimen with clean cloth, then with a cloth wet with a thin, low viscosity oil, then operates the specimen for a few dozen or hundred stress reversals, wipes specimen clean again, dusts on fine Fuller's earth, and stresses specimen again for a short time. Oil caught in any crack will mark the Fuller's earth coating.

We have used a somewhat simpler method: A small amount of soap solution is poured on the suspected area of the fatigue specimen either with the test running or stopped. When the test is started, any crack present will be indicated by the formation of a line of soap bubbles. In this way very minute cracks may be detected. (G. B. KINER, Plant Metallurgist, St. Paul Works, International Harvester Co.)

Wax Impregnated Broadcloth Superior for Rough Polishing

AS EVERY metallographist knows, the rough polishing step is the most important one in the entire process of preparing a specimen for examination, for it is then that polishing pits and flowed surface metal may occur. The pits are places where non-metallic inclusions are dragged out, and they give the steel an exaggerated appearance of dirtiness. Flowed surface metal is also brought about by dragging; the specimen must be repolished and re-etched a number of times before the true structure is revealed.

Recently learning from Joseph Vilella of the U.S. Steel Corp. Research Laboratory that a wax covered canvas cloth and 600-mesh alundum had been successfully used, I found similar success with broadcloth, paraffin, and levigated alumina.

Unetched Micros of Steel (Same Location), Polished Identically Except for Rough Polishing Step

Exaggerated size of pits where inclusions were dragged out by abrasive on long nap broadcloth

True condition of steel; inclusions retained during rough polishing with levigated alumina on wax impregnated broadcloth

Procedure is as follows: About ¼ lb. of paraffin is melted in a 500-cc. beaker. The piece of broadcloth is then dipped in the melted paraffin, holding the cloth by the four corners which, because they remain dry, can be used to pull the cloth tightly over the wheel. It is important to warm the wheel under the steam faucet just prior to covering it with the cloth, as this will prevent the paraffin from solidifying in lumps. After the wheel has cooled, it is ready for use. A solution of alumina levigated for 20 min. is suitable, to which has been added a small quantity of liquid soap (necessary to make the solution adhere to the wax surface).

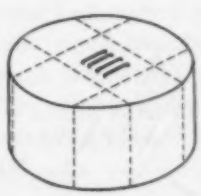
The surface of the wheel contains thousands of tiny holes, caused by the way the paraffin freezes in the nap of the cloth. It is these minute holes which hold the alumina particles, thus giving it its excellent cutting quality. This wheel not only removes scratches from the 000 grit faster than the plain broadcloth, but also preserves the non-metallic inclusions and minimizes the presence of flowed metal. With careful manipulation the wheel will outlast the customary rough polishing one.

Accompanying pictures, taken of unetched specimens at 100 diameters, show the results after rough polishing on the plain broadcloth and on the paraffin impregnated broadcloth, respectively. You will note the exaggerated appearance of dirtiness in the first picture. The two are true representative spots on the same specimen; after the first was taken the specimen was reground and repolished for the second micro. (Louis A. Nowell, Jr., Metallurgical Laboratory, U.S. Naval Engineering Experiment Station)

Normal Sections of *Fine* Wire

Asked to mount reasonably true cross-sections of No. 37 B&S gage (0.00445 in.) resistance wire for microscopic examination of roundness, we proceeded as follows:

Approximately ¼-in. long samples (five or six in number) of the wire in question were mounted in a bakelite press in the conventional manner for *longitudinal* sections. The mounting thus obtained was sectioned along the dotted lines



shown in the above sketch. This produced a rectangular shaped specimen of convenient size for re-mounting in such a way that the wire samples were running perpendicular to the plane of polish. Grinding and polishing for microscopic examination was then carried out in the usual way. (R. G. Sartorius, Metallurgist, National Lock Washer Co.)

American Society of Mechanical Engineers, in its 64th Annual Convention, gave an unusual amount of time to problems of tool design, and machinability. Especially noteworthy are the revolutionary "negative rakes" and the cyclonic speeds, not only on aluminum and magnesium, but also on steel

Tools for High Speed Milling— and for Shell Forging

A GREEN OPERATOR, machining aluminum on a Farnham spar miller in a West Coast airframe plant, accidentally ran into a steel clamp. He was using an 8-in. carbide cutter running at 3000 rpm. with a feed of 50 in. per min. The steel clamp was neatly cut, and the cutter was uninjured, conventional theories of machining to the contrary! To this experience is owed a new field of research, and "progress reports" occupied a considerable portion of the generous space given to metal cutting at the 64th annual meeting of the American Society of Mechanical Engineers held recently in New York.

The Production Engineering Division conducted a symposium on high speed milling of both steel and light metals. Matter relating to steel covered the use of negative rakes with carbide tools and gave the results of test runs, theories of negative rake machining, material requirements of tools, and the broad specifications for machines to handle the increased load in this novel type of operation.

The aircraft industry on the West Coast has a research program well under way, studying the high speed milling of steel, although the optimum speeds, feeds, and tool geometry are not yet known. Some interesting data include the fact that steel of 210 Brinell hardness (rather soft for good cutting in a conventional way) has been machined at 3000 rpm. with feed of 60 in. per min., using no coolant and producing a finish approaching perfection. In many tests the only limit found was the available power and mechanical complications such as chip removal, vibration, and fixtures.

Results of experiments to explore the theoretical causes for the favorable results with negative rakes were given by Hans Ernst of Cincinnati Milling Machine Co. The cutting pressures on tools using 10° true positive rake and 10° true negative rake were compared at various speeds. The positive rake had an increase in pressure with speed in the range of the curve shown. The negative rake, although showing higher pressures at low speeds, had a downward slope, crossing the positive rake curve at approximately 650 ft. per min. The reduced pressure of negative rake cutters at high speeds, together with the stronger tooth form, and the great ability of carbides to resist the added abrasion, explain some of the phenomenal results. The belief was expressed that the temperature of the chip approaches its melting point. This great softening of the metal being cut would also help to explain its high machinability at high speeds.

Cutters must be designed for the special requirements of high speed milling. Massive construction must be used throughout, with dimensions approximately twice that of cutters operating at low speeds. Flywheels are added to absorb the energy of the impact, tooth to work. The high damping characteristics of cast iron make it ideal for the cutter body. The number

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of teeth must be reduced from that generally used in milling; a rule-of-thumb policy followed by one speaker is diameter in inches plus two, although this was thought by others to be on the high side. Arthur Schwartz of Bell Aircraft Corp. said that commercial milling cutters have so many teeth that if the printed instructions of the manufacturers were followed about the chip load for each blade, and if the cut were at all heavy, either the cutter or the arbor would break, or the motor stall. He firmly believed that the amount of material removed per min. could be doubled (steel or ferrous materials) if the right cutter, properly ground, would be run at the right speeds and feeds.

Discussion of this point was long and loud in lobbies and corridors. Evidently many of the standard stock cutters, ordinarily thought of as "high grade", do not produce the accuracy and high finish nor the production required by aircraft and aircraft engine manufacturers. One West Coast engine manufacturer takes a cutter which has extremely close tolerances in diameter and width, and then *polishes* every part of it except the cutting edges. He simply could not emphasize enough the trouble experienced in the industry due to cutters with poorly machined (milled or turned) bodies. Some really remarkable results were obtained after standard commercial cutters had been converted into tools satisfactory to aviation standards.

Another definite instance quoted was a saw for milling fins in cylinder heads, which runs at a surface speed of 3500 ft. per min. At that speed, unless the saw is perfectly balanced, the saw vibrates badly, as a result of which the sides of the fins are extremely rough. Besides that, this speed is just short of the critical moment where saws will begin to "flutter" — sometimes they do, if they are too badly out of balance. The width of the individual teeth varies as much as 0.0013 in., all of which helps to unbalance the saw when running at high speeds. This being one of these special saws which has but six or eight teeth, the form of each tooth is very important not only from the standpoint of keeping the saw in balance, but of throwing off chips readily. Here again it was found necessary to polish the "gullet", adjust the form of the saw tooth (that is, the back edge of it) and to do this and that and the other thing to achieve perfect balance and to remove all tool marks of any kind, which were found to create resistances detrimental to satisfactory high speed functioning.

High speed milling will require added facilities in machine tools. A ten-fold power increase is desired, with easily adjustable ranges of speeds and feeds. Rigidity in all parts of the construction is absolutely necessary. Chips flow in great volume, and convenient handling methods must be available. Cutting fluids, if used at all, must be used in very large volumes. More adequate fixtures must be designed, since the insertion of the piece often becomes the most time-consuming part of the whole operation.

The proper approach for those wishing to experiment with high speed milling was given. Cutters are expensive and can be easily ruined so that it was recommended that the beginner start with a fly cutter and from this develop the proper angles. A flywheel should be inserted to smooth out the cut. Added rigidity can be obtained by using bulky cutters and climb milling. An air blast was suggested for removing the chips. It was pointed out that good results have been obtained with zero rake, which also simplifies sharpening. If sulphurized cutting fluid is used, the least objectionable corrosion occurs with tungsten carbide tools.

Metal Cutting Research

The A.S.M.E. Research Sub-Committee on Physics of Metal Cutting, and the Special Research Committee on Cutting of Metals contributed several important papers to the meeting. Orlan Boston of University of Michigan has prepared a proposed "Standard Tool Life Test for Evaluating the Machinability of Single Point Tools, Cutting Fluids, or Materials Cut". The many variables such as equipment used, merits of tools, surface quality, form of chips, forces and power involved, depth of cut, feeds and speeds, cutting fluids used, materials cut as to physicals and chemistry, and surface conditions produced, all must be held constant in order to reproduce results. When this is done the results are expressed in three variables; tools, cutting fluid, and materials cut. When any two of these are constant the third may be evaluated in their terms. Professor Boston, together with H. L. Moir, E. M. Slaughter, and W. H. Oldacre, also gave a paper on "Practical Cutting Fluid Recommendations" which was printed substantially in full in the October issue of *Metal Progress*.

M. Kronenberg's paper on "Cutting Angle Relationships of Metal Cutting Tools" derived mathematically the true rake angle t in terms of the corner angle c, radial rake r, and axial rake a for a face mill, or effective side cutting edge angle c, side rake r, and back rake a for a lathe tool. This relationship is expressed by the following formula:

$$\tan t = \tan r \cdot \cos c + \tan a \cdot \sin c$$

The emphasis of Dr. Kronenberg's paper is in the method of altering the true rake angle by changing the corner angle. If the axial and radial rakes are both positive or negative, the true rake will always be positive or negative but can be varied in degree. If they are of different signs the true rake can be made either positive or negative. At different depths of cut a change in true rake can occur due to the different corner angle. Again, a curved contour will vary the true rake along the cutting edge and a tool can have two or more true rake angles. It was pointed out in the discussion that additional variables can occur, and they must be taken into account for some types of metal cutting.

A metal cutting nomograph was presented by W. W. Gilbert and W. C. Truckenmiller of the University of Michigan, which gives a rapid solution of the more important mathematical laws governing metal removal, and which can be used to obtain the maximum output of a machine when constants for the tools and materials are known. The required constants are tool types (such as carbon, high speed, cast or carbide) and the S.A.E. grade and Brinell hardness of the steel to be cut. If the reduction of area is also given the results are more accurate, through the use of the Janitzky formula. No allowance is made for cutting fluids; if used they will increase cutting speed by 15 to 30% for emulsions and 10 to 25% for oils. With the above data known and a desired tool life stated, a combination of depth of cut, feed, and speed, together with the power, can be found.

A paper by V. H. Ericson of The Norton Co. on "Increasing Tool Life by Better Tool Finishing" again verified the many reports mentioned above (page 92) and showed an increased life resulting from finer finishes. Carl J. Wieberg of Wright Aeronautical Corp. recounted the advantages obtained in his organization through standardization of cutting tools. He argued for its adoption by the entire metal industry.

Forging of Steel Shells

The final report of the Research Committee on forging of steel shells gave the results of that part of their investigation which the War Department has released. The matter dealt mostly with the nature of the very complex problem of metal flow in the forging operation, and should have a post-war metallurgical value in the production of all hollow cylinders or pierced forgings.

Generally, shell forging involves three separate operations: piercing, drawing, and nosing, each of which is a separate problem. Piercing requires the highest pressures and to keep this low enough for the tools requires the maximum elimination of axial flow, development of optimum punch geometry, lubrication of punch in the cavity, and operation in the upper limit of permissible temperatures.

Some axial flow always occurs, even in the most favorable operation, or where there is no increase in length. The committee used inserts and studed their macrostructures, thus following the movement of metal during piercing. It was shown to be of a complex nature. That part next to the punch moves forward and the boat tail endures a combination of compression, tension, and shear. The cavity required for best ballistic properties is not suitable for a piercing tool and must be produced on the draw bench in operations which follow. The pressures required have been worked out by W. Trinks of Carnegie Institute of Technology, who gave the report on shell piercing.

Lubrication in the cavity becomes a problem since temperatures are far above the vaporization point of any hydrocarbon. A mixture of coal and sawdust gives the best results as a gas is generated which reduces metal-to-metal contact. Temperatures should be as high as possible since pressure requirements rise drastically when the metal cools below 2100° F.

George Sachs of Case School of Applied Science dealt with the drawing operation. The forces became too involved for theoretical treatment so lead slugs were used to develop the process and the results verified with steel. Temperatures were found to be the greatest variable; in a typical case it required a 1000-lb. pressure at 2300° F. against 5000 lb. at 1800° F. Cast iron draw rings permitted a reduction of 25%, whereas 10% is about the safe limit for steel tools. Recommended lubrication is grease and graphite. The mathematics of the draw bench have been worked out in detail using much of the experience of the rolling mill.

The nosing of steel shells is the easiest of the three operations, as reported by A. Nadai of Westinghouse Research Laboratories. Since radial compression and bending are the forces involved, the pressures are not high, and in the 105-mm. size and smaller, it can be performed cold. When the shell is heated, the temperature gradients become a problem and induction heating is recommended. Whereas hydraulic equipment has been found best for piercing and drawing, a mechanical press is suggested for this operation since the stress in the nosing cycle corresponds nicely with that developed by the crank.

A method is outlined whereby a series of Jominy end-quench bars may be used to predict the structure and hardness of a steel when cooled in normal quenches. Such data are quickly obtained and are especially valuable in deciding whether a questionable heat can be die quenched in the regular routine

Continuous Cooling Transformation Diagram,

From Modified End-Quench Method

ONE OF THE IMPORTANT milestones in our approach to an understanding of the hardening process was the publication of researches on the isothermal transformation of austenite, researches starting in 1929 in the U. S. Steel Corp.'s Research Laboratory and well summarized by Davenport in the Campbell Memorial Lecture (1939 ⊕ *Transactions,* page 837). The first publication in 1930 started many other studies with the result that information on *isothermal* transformation is increasing steadily in volume and precision. However, data on transformation during *continuous cooling* are not plentiful.

It will be recalled that, in isothermal transformation, a piece of steel is quenched from the hardening temperature in a bath of melted metal or salt at a desired high temperature, and left there until the austenite changes into a new structure stable at that temperature. Naturally the piece must be small enough so that *all* of the metal (or that portion which is to have the controlled microstructure) be cooled from furnace to bath temperature very rapidly. Obviously most machine parts are too large for the requirement just stated; to the industrial metallurgist, therefore, information about transformation during normal continuous cooling may usually be a more profitable aid in the study and perfection of production heat treating.

Grange and Kiefer (*Transactions* ⊕, 1941, page 85) point out that *direct* experimental investigation of transformation on cooling is extremely difficult except in sluggish steels, and requires a metallographer who is able to recognize clearly the different constituents in the resulting mixed microstructure. They studied a bar of S.A.E. 4340, furnace cooled at various steady rates, and also developed an interesting empirical method of deriving the cooling diagram from the isothermal diagram. They found, for example, that austenite in this steel started to precipitate ferrite in 200 sec. if held constantly at 1200° F., but that on steady cooling at 35° F. per sec., this reaction was "super-cooled", starting at 1110° F., 500 sec. after cooling started.

The method described in the following permits one to draw lines on a time-temperature diagram showing the beginning of various reactions occurring during the cooling of steel, such as the appearance of ferrite, pearlite, or bainite from the mother austenite. The accuracy is ample for practical applications, and, contrary to Grange and Kiefer's method, is applicable to steels that react relatively fast — that is, to most mod-

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Propeller Division
Caldwell, N. J.

ern alloy steels. This new method is simple and sufficiently rapid to be useful to a practicing metallurgist who requires a more thorough understanding of the reaction characteristics of a steel than can be obtained through trial and error heat treating tests, or from a standard end-quench curve. Required equipment exists in all well-equipped laboratories — namely, a fast curve-drawing temperature recorder, a Jominy end-quench fixture, proper tool hardening furnace, Rockwell hardness tester, stop watch, and brine tank. In this work we used a ½-in. diameter specimen to fit the available stock, rather than the "standard" 1-in. specimen; to eliminate erratic cooling due to the tong effect it was found desirable to screw a short bolt into the top end of the specimen to serve as a handle in transferring specimen from furnace to Jominy fixture, and later from fixture to brine quench.

Experimental procedure will now be explained, step by step.

1. Obtain cooling curves for a sufficient number of positions along the end-quench bar. This step needs to be performed only once for each hardening or solution temperature.

In our experiments, the cooling curves were obtained with a Speedomax using 20-gage chromel-alumel thermocouples, whose junction was inserted in a $\frac{1}{16}$-in. hole $\frac{1}{16}$ in. deep. The hole was then closed by peening. Figure 1 shows the assembly of specimen and thermocouple. Such cooling curves were recorded during end-quenching the sample from 1700° F. Positions were as follows, measured from the quenched end: ⅛ in., ¼ in. and up to 1 in. by eighths; 1¼ in., 1½ in., 2 in. and 2½ in. The early portions of these curves are plotted on Cartesian coordinates in Fig. 4, page 97.

2. Machine a number of ½-in. diameter end-quench test pieces of each steel to be studied. For the purposes of this article two heats of 6130 chromium-vanadium steel were selected. Their chemical analyses were within specification, and calculated hardenabilities not too divergent. However, their end-quench results were quite different, as shown in Fig. 2 (page 94). Analyses follow:

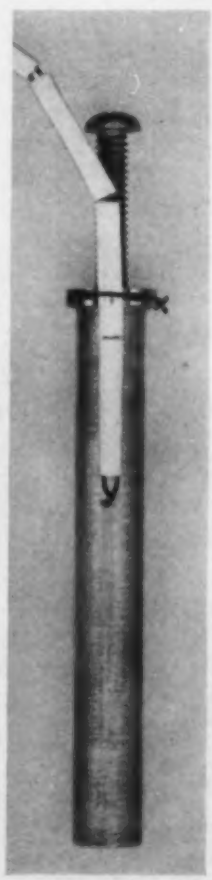


Fig. 1 — End-Quench Specimen With Thermocouple Attached, Ready to Determine Cooling Curve 2½ In. From End of Bar. Note bolt screwed into top for handling specimen from furnace to fixture, and fixture to brine tank

	Heat G-20030	Heat 19380
Analysis		
Carbon	0.29%	0.35%
Manganese	0.71	0.67
Silicon	0.36	0.45
Phosphorus	0.011	0.010
Sulphur	0.008	0.007
Chromium	0.98	0.98
Vanadium	0.20	0.23
Hardenability by		
Grossmann's data*	2.22	2.14
Crafts and Lamont's data†	2.40	2.32
Shepherd grain size (1700° F.)	8½	9

*Tech. Pub. No. 1437, A.I.M.E., Feb. 1942
†Tech. Pub. No. 1542, A.I.M.E., Jan. 1943

3. Place a group of test bars (21 in number in our routine) in the heating furnace and bring them to the quenching temperature, 1700 ± 5° F., meanwhile protecting them against oxidation in an approved way. Time to take a hot bar from the furnace, put it into the quenching fixture and start the water will be a constant for a first-class operator; we find it takes 3 sec. in our laboratory. The first sample is end-quenched in the cooling jet for 10 sec. and immediately transferred to iced-brine at 32° F. The second sample is end-quenched for 15 sec. and then transferred to iced-brine. The third sample for 20 sec., the fourth for 30 sec., and subsequent samples for times increasing by 10 sec. Elapsed times from furnace to brine tank are therefore 13 sec., 18, 23, 33, 43.....203 sec.

4. Carefully grind a flat, 0.015 in. deep, along two parallel sides of each bar and take Rockwell hardness tests along the length in the usual way. Representative curves for heat 19380 are shown in Fig. 3. It will be observed that end-spray for 10 sec. transforms only the very end of the bar, for even the spot ⅛ in. from the end develops a higher hardness than the end after quenching in brine. Fifteen seconds in the Jominy spray transforms this spot completely; after quenching this bar and all others in brine, the spot measures C-54.5 ± 0.5. Similarly, the region ¼ in. from the end is transformed by the end spray to Rockwell C-54 hardness in 20 sec.; the spot ½ in. from the end to C-47.5 ± 0.5 in 50 sec. and so on. Knowing the time-temperature cooling curves of each of these spots (determined in step 1) the condition of the steel at any time during the quench, prior to reaching its eventual hardness, may be estimated.

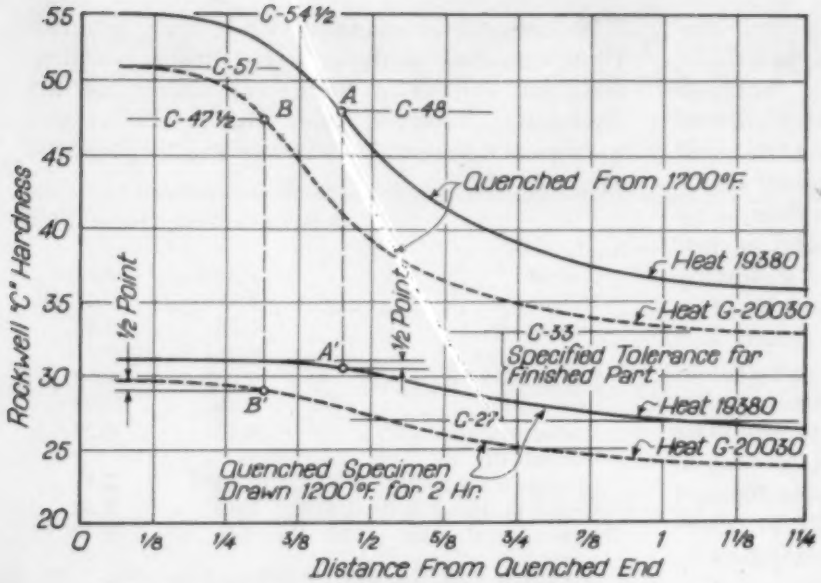


Fig. 2 — Jominy End-Quench Hardness of Two Heats of 6130 Steel. Upper curves: Hardness readings after quenching from 1700° F. Lower curves: Hardness readings repeated after specimens were drawn 2 hr. at 1200° F. Shepherd grain sizes: Heat 19380, 9; heat G-20030, 8.5

5. In the time-temperature diagram containing the cooling curves, enter the hardness of each station of each Jominy bar on the time ordinate corresponding to the end-quench period. Figure 4 shows the results for heat No. 19380. Points denoting a change in hardness of a certain station from one end-quench period to the next may be connected by "hardness levels" or contours that will separate one hardness field from another. Each field will contain an arbitrary range of hardness, as desired by the investigator to fit the conditions he regards as important.

Such a plan has been followed in Fig. 4. The dotted lines show hardness levels of C-53, C-45 and C-37.5, similarly derived, for heat G-20030, and it will be observed that this heat is not nearly so hardenable as 19380, despite its similarity in chemical composition, and the fact that the computed hardenability is slightly higher. This is, indeed, already shown by the conventional end-quench curves of Fig. 2. No explanation of this apparent anomaly is at present available. *Maximum* hardness of G-20030 (C-51) is considerably lower than that of 19380 (C-54.5), as would be expected from the respective carbon contents.

6. Figure 4 can be used for control of quenching operations. Microstructure can be inferred from the hardness. A fair amount of transformation, such as ferrite precipitation, may have but slight effect on the Rockwell reading. However, if one is concerned with the actual micro-constituents, judiciously selected sections may be examined metallographically. This has been done for heat 19380, and the results assembled in the large graph, page 98. This sheet shows in fine lines all the cooling curves of Fig. 4, replotted on semi-logarithmic coordinates. The heavy black curves outline the regions where the various micro-constituents exist. The curves on this sheet, therefore, comprise a transformation diagram for continuous cooling at rates approximating those obtaining in commercial quenches.

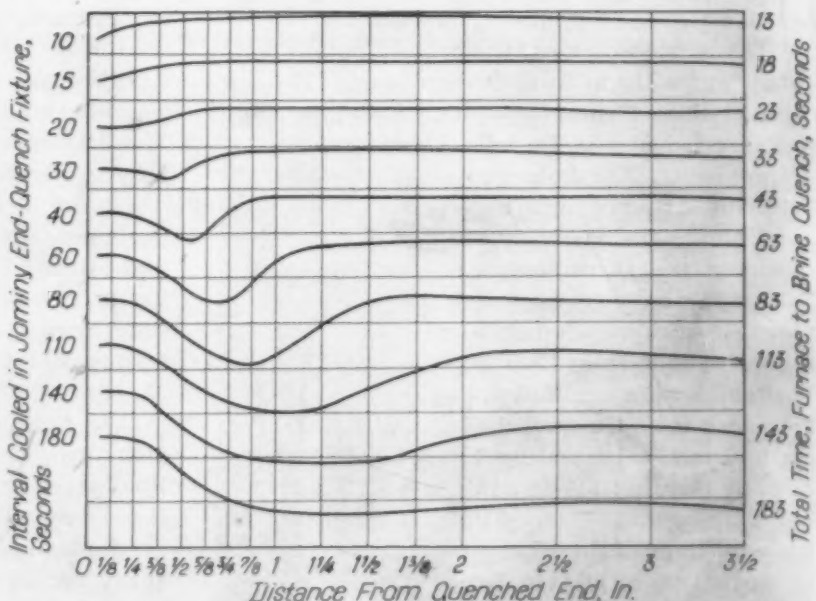


Fig. 3 — Hardness Surveys on Representative End-Quench Bars of Heat 19380, Brine Quenched After Indicated Time in Spray Fixture. (Three seconds are needed to transfer sample from furnace to Jominy fixture)

Utility of the Data

Davenport's "S-curve" of eutectoid carbon steel shows that the time for transformation to begin is shortest at 1100 to 900° F. Ferrite pre-

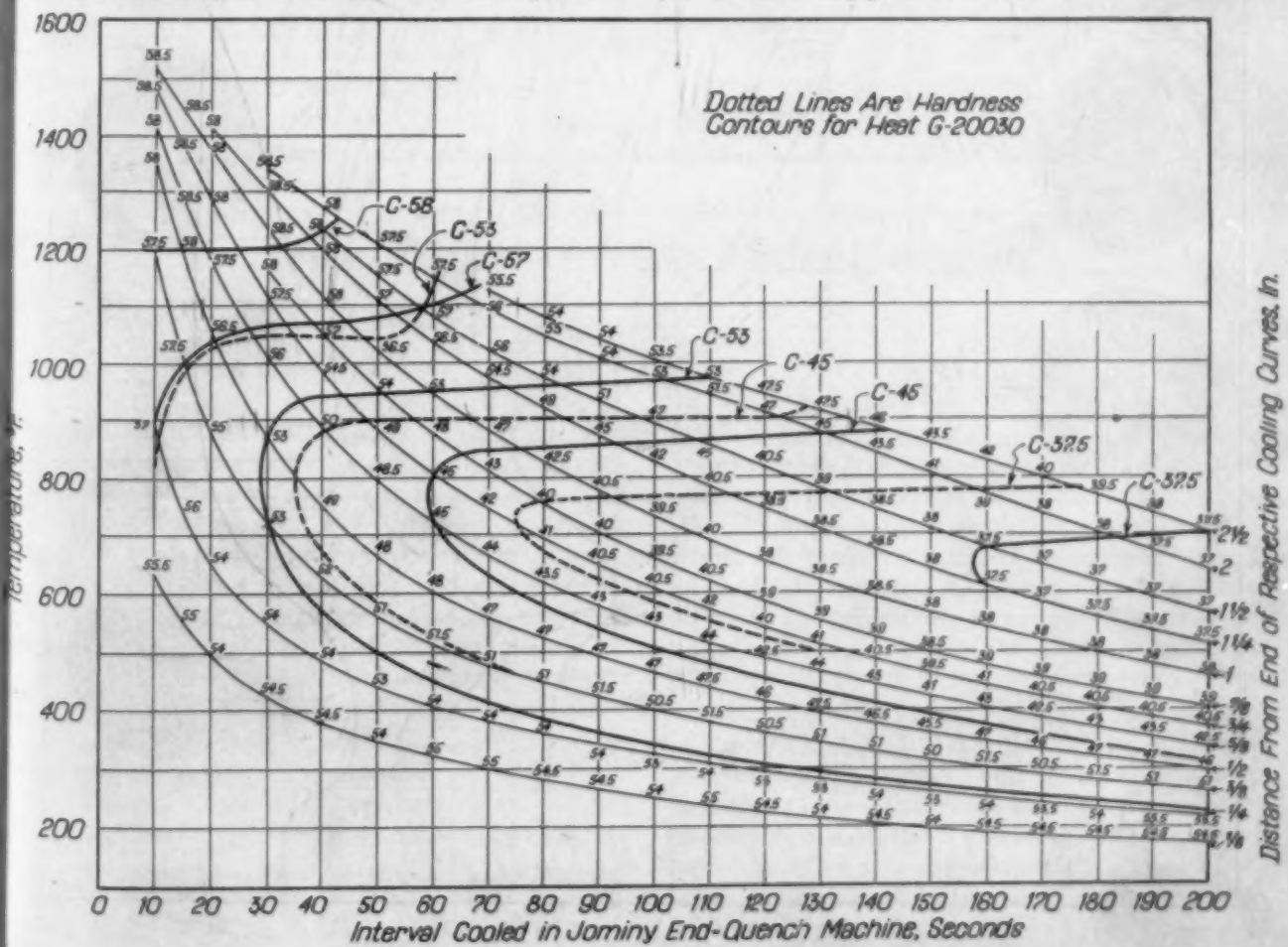
cipitates directly from the austenite in S.A.E. 6135 steel (as shown on page 98) within 10 sec. Cooling rate through this range is therefore the critical item in correct quenching practice. *Time* for cooling from 1100 to 900° F. at various positions on the ½-in. Jominy end-quench bar can be scaled directly from the cooling curves in Fig. 4, and is tabulated on page 99. Given also are Jominy's figures for the 1-in. test bar (*Transactions* ⓐ, June 1938, page 574) quenched either from 1700 or from 1425° F. It will be seen that the ½-in. bar used by us cools faster through the dangerous range.

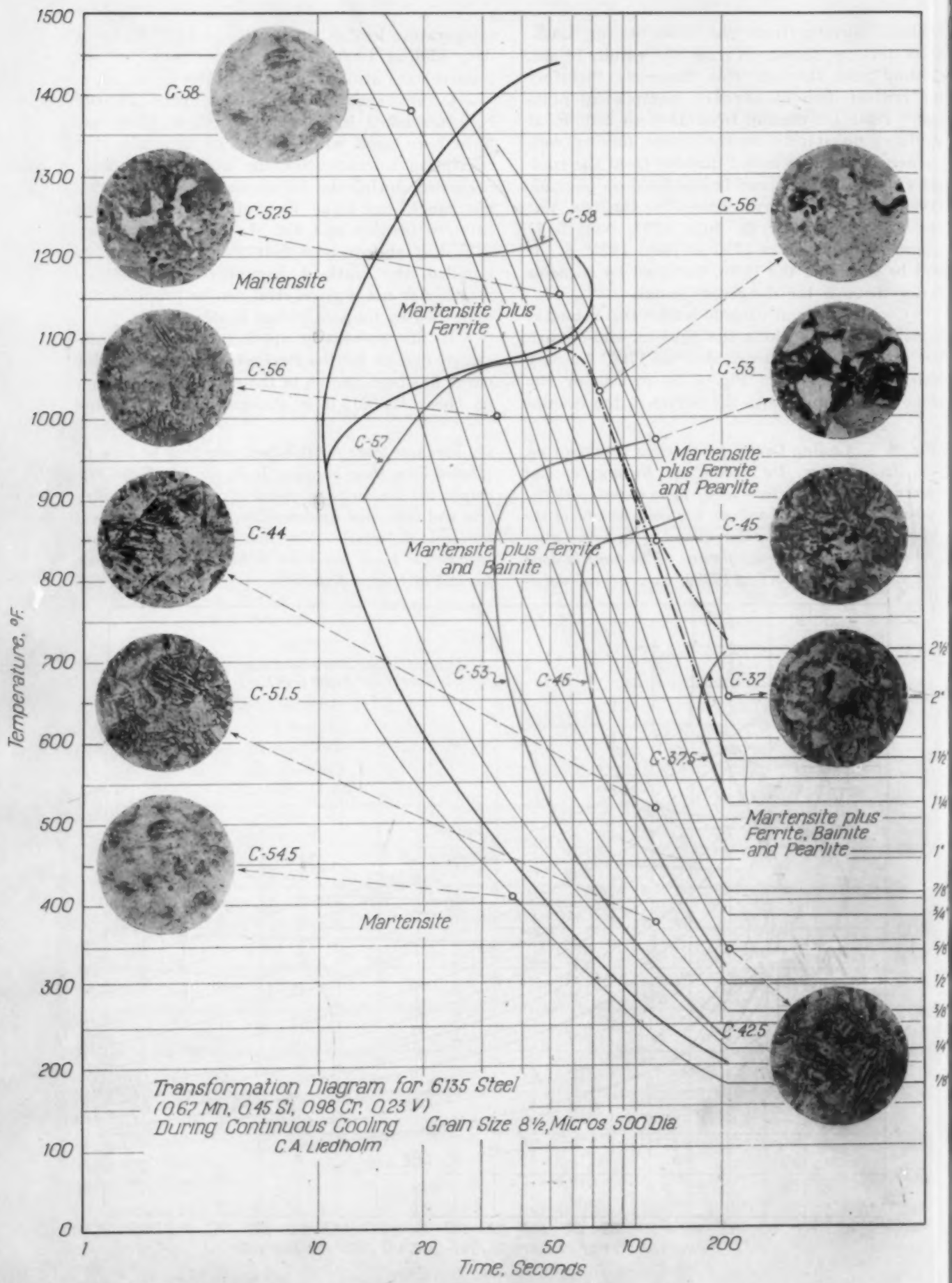
Cooling rates at various temperatures and at various positions along the ½x4-in. end-quench bar of 6135 steel, quenched from 1700° F., may also be derived from Fig. 4 by measuring the slope of the tangents to the curves at the desired temperature levels. Such rates at 1300° F. (near Ae_1) and at 1000° F. (near the "nose" of the S-curve) are also given in the table.

Curves such as plotted on page 98 can be constructed in a relatively short time, and have been used with success to determine the maximum tolerance for the unavoidable delay occurring during the die quenching of parts that are much too large for split-second handling between furnace and die. In fact, since experience has shown how fast these parts can be handled, the method described will indicate whether or not a given steel can be properly die-quenched by the established routine.

If the eventually applied quench is sufficiently drastic for the steel whose transformation curve has been shown in the curve sheet on page 98 (heat 19380), it is obviously safe to permit

Fig. 4 — Cooling Curves for Various Positions on the Jominy Bar Are Plotted on Rectangular Coordinates. At intersections of these curves with the 10-sec. ordinate the hardness has been entered of the respective point on the bar quenched in brine after 10 sec. in the end-quench fixture. The same is done for the other bars from heat 19380. Contours representing hardness levels for this heat may then be drawn. (Dotted lines show hardness levels for heat G-20030; despite the similarity in chemical composition, grain size and computed hardenability, the hardness levels are quite different). Note that time scale does not include the 3 sec. necessary to transfer sample from furnace to Jominy fixture




1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Temperature, °F.
1
10
20
50
100
200
Time, Seconds
C-58
C-525
C-56
C-44
C-515
C-545
C-53
C-45
C-37
C-375
C-425
Martensite
Martensite plus Ferrite
Martensite plus Ferrite and Pearlite
Martensite plus Ferrite and Bainite
Martensite plus Ferrite, Bainite and Pearlite
2½
2"
1½
1¼
1"
⅞
¾
⅝
½
⅜
¼
⅛
Transformation Diagram for 6135 Steel
(0.67 Mn, 0.45 Si, 0.98 Cr, 0.23 V)
During Continuous Cooling Grain Size 8½, Micros 500 Dia.
C.A. Liedholm

a quench delay of 10 sec. even when the precipitation of ferrite must be completely avoided. If *some* transformation can be tolerated, but the as-quenched hardness remain at least as high as Rockwell C-53, the quench for the same heat can be delayed for 32 sec.

Similar curves for heat G-20030 show that if it is to be quenched to Rockwell C-50, the delay must be less than 20 sec.

Derived Data From Cooling Curves in Fig. 4

Position	Seconds to Cool From 1100 to 900° F.		Cooling Rates, °F. per Sec. (½-In. Bar)		Half-Temperature Cooling Time
	½-In. Bar	1-In. Bar	At 1300° F.	At 1000° F.	
⅛ in.	1.5	2	445	140	9
¼	4	6	99	48.5	14
⅜	7	10	50	27.6	22
½	10	14	34	19.7	32
⅝	14	18	25	13.5	43
¾	17.5	22	19.3	11.7	52
⅞	21	25.5	16.9	9.7	61
1	25	29.5	14.2	8.1	72
1¼	32.5	37	11.1	6.2	88
1½	40	45	9.1	5.0	104
2	53	60.5	7.3	3.9	128
2½	61	..	6.7	3.7	144

For the propeller parts to be made of this particular steel, the specified Rockwell range after quenching and tempering is C-27 to 33. Figure 2 shows that incomplete quenching (as in heat G-20030) leads to more rapid softening on tempering than does quenching to a fully martensitic structure. Points A and A′ in the same figure, however, show that for heat 19380, a standard draw results in a difference of only Rockwell C-½ between the as-quenched hardnesses of C-54.5 and 48. The same Rockwell difference after tempering of heat G-20030 is obtained between as-quenched hardnesses of C-51 and 47½ (points B and B′).

The indicated method of determining whether quenching has been adequate or not is as arbitrary as selecting a microstructure containing 50% martensite as the minimum hardened condition, but it appears to be proper when specifications call for a narrow hardness range to be met by large parts of greatly varying section.

Acknowledgment is due to the following Engineering Materials Laboratory personnel: R. Bentel and A. Rush, who performed the experimental work; W. C. Coons, who prepared the photomicrographs.

Our Debt to the Metallurgist

By L. W. Law*

Those who, like myself, have spent most of their lives in the production and distribution of heavy machinery cannot fail to be aware of the fact that the improvements which have been made would have been quite impossible without that ardent and unstinted support rendered by the metallurgist; in fact, it can be truly said that the metallurgist must always be at least one jump ahead of the engineer, otherwise real progress is barred. While this is rather obvious in the field of aeronautics, it is not so evident in land-borne equipment.

Cutting Tools — In the early years of the present century, when my first experience of machine shop practice was gained, the cutting speed of cast iron was about 20 ft. per min., of gun metal about 25, and of mild steel about 15. At that time self-hardening steels (containing about 6% tungsten, such as "Mushet") were in vogue, and plain cast steel tools were in common use. Nowadays with tool-cutting alloys and carbides, cast iron and mild steel may be machined at about 400 ft. per min., and non-ferrous metals up to practically any speed which the machine will allow. This 20-fold increase in machining speed has had a tremendous influence upon keeping down the cost of machinery of almost every description, and particularly of mass-produced articles. Here is a very striking instance of the work of the metallurgist being of benefit to the community as a whole; it has certainly helped to

*Abstract from Presidential Address to Birmingham (England) Metallurgical Society, *The Engineer*, Oct. 1, 1943, p. 264.

raise the standard of living by bringing the cost of many articles within reach.

Powder metallurgy is not new, but its development during the last few years has been almost miraculous. What formerly took several hours of a highly skilled mechanic's time can now be accomplished in a few seconds. The degree of accuracy is unimpaired, and precision down to a thousandth of an inch is obtained. Today thousands of different components of ships, locomotives, airplanes, motor cars, tanks, and radios are pressed out of powder. The smallest weighs 0.05 oz. and the largest 65 lb. A certain amount of work has already been carried out in connection with the centrifugal pressing of powders.

Stainless steel is used now for a great variety of purposes; in mining, civil and marine engineering it has proved of the greatest value, due to its resistance to the action of mine and sea water. Its resistance to nitric acid has opened up a new field in the production of ammonia. In the dyeing industry the wooden vat has been almost superseded by the stainless steel vat, and stainless steel is now commonly used in the milk and brewing industries, its superiority from the hygiene point of view being unchallenged. Nickel, monel, and silver are also much used in chemical plants.

Oil engines were only possible after the advent of improved metals, permitting higher speeds and higher pressures to be employed.

Here mention might be made of pearlitic iron for cylinder heads and liners, the heat resisting properties of which, combined with its special strength, rendering it peculiarly suitable.

High strength steels for such parts as inlet and exhaust valves have been developed by the addition of other elements, such as nickel, chromium, molybdenum, vanadium, and tungsten, which have considerably raised the limits of fatigue strength, and also reduced the dangers arising from mass effect during heat treatment.

For traction work and other cases where it may be desirable to keep the weight of an oil engine down to the minimum, the building up of the frame, crankcase, base plate, and other important parts from fabricated or welded steel plates, instead of making them of cast iron has been successfully accomplished.

Water — the daily consumption of water per head of population in this country was 30 gal. at the beginning of the present century, as compared with 7 gal. per head 50 years earlier. Today the consumption has risen to nearly 40 gal. per day per person. The question may arise as to what connection there is between the metallurgist and the supply of water to large towns and cities. A visit to one of the earlier pumping stations, followed by a visit to one of the modern installations, would supply an eloquent and at the same time an adequate answer to that question. The centrifugal pump has taken the place of the reciprocating pump, and it is not uncommon for these to run at a speed of 2000 rpm., driven perhaps by a steam turbine running at 8000. Space occupied is only a fraction of that of the earlier plant, the capital cost is lower, and the resultant cost of the water as delivered. The metallurgist has also been to a large extent responsible for the economical manufacture of the correct metals in water pipes. The benefits accruing to the community in the way of health and happiness as a result of an abundant water supply cannot possibly be over-estimated.

Turbine Blades — The finding of the most suitable metals for turbine blades has been a difficult proposition, and various metals and alloys have in turn been used. Stainless steel is the one most used today, and has enabled the steam pressures and temperatures to be raised from what was common practice in the year 1900 (160 psi.) to 1300 psi. and from 400 to 950° F. The effect of this has been to raise the efficiency of the turbine to about 33%. The mean blade speed of a turbine may exceed 7 miles per min., with a consequential tangential stress at the top of the keyway in the bore of 25,000 psi. Further, the steam passing through the closed system takes about 100 min. from the time it enters the condenser until it re-enters the turbine at the first stage. As compared with this time of preparation, the time the steam takes to pass through the turbine and do its useful work is about 0.08 sec.!

Electric Transmission — Considerable economies in the transmission of electricity have been effected in recent years by increasing the span of overhead conductors by the use of *(a)* copper-cadmium conductors, *(b)* steel-cored aluminum, or *(c)* steel-cored copper.

For underground transmission the fatigue, strength, and corrosion resistance of lead cable sheathing has been considerably improved by the introduction of small amounts of other elements, such as cadmium, antimony, and tellurium.

Transformers have only been brought to their present state of perfection by the use of 4% silicon iron.

The magnetic properties of irons have been considerably improved by the addition of cobalt, and still further by the addition of nickel and aluminum simultaneously, together with special heat treatment.

NICKEL AIDS THE AUTOMOTIVE INDUSTRY

to KEEP 'EM ROLLING!

Using ingenuity and "know-how" born of long experience, automotive engineers designed the phenomenally successful transport equipment that now speeds the United Nations on the road to Victory.

Built to take punishment far above peacetime requirements, these specialized military vehicles are being produced in quantity by the mass-production methods that have amazed the world. From North Africa to the South Pacific, these trucks, jeeps, tanks and half-tracks have repeatedly met wartime demands for stepped-up performance.

This kind of engineering-thinking pioneered the application of Nickel alloyed materials. Now, when uninterrupted operation is so vitally important, the continued and widespread use of Nickel is clear evidence of its many advantages.

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Today, maintenance crews on far-off battle fronts are learning what metallurgists and engineers here long have known . . . that, properly used, Nickel aids to "keep 'em rolling."

For years the technical staffs of International Nickel have been privileged to cooperate with automotive engineers and production men . . . men whose work is now so necessary to the Nation. Counsel, and printed data about the selection, fabrication and heat treatment of ferrous and non-ferrous metals is available upon request.

★ *Nickel* ★

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THE INTERNATIONAL NICKEL COMPANY, INC., *67 Wall St., New York, N.Y.*

ALUMINUM ALLOYS

Compositions, Properties, and Designations of American Commercial Alloys

Compiled by H. S. Jerabek, University of Minnesota, from Handbooks and Specifications of American Society for Metals, American Society for Testing Materials, Society of Automotive Engineers, & Aluminum Co. of America

Wrought Alloys

Designations			Composition (Aluminum = Balance)					Form Tested	Tensile (b) Strength, 1000 Psi		Yield (b) Strength, 1000 Psi		Elong., % in 2 In.		Brinell Hardness	Shear Str. (b) 1000 Psi	Endur. Limit (c) 1000 Psi	Cold Bend Test (d)	Corrosion Resistance in NaCl (e)		Alcoa No.	Characteristics and Uses
S.A.E. No.	A.S.T.M. Specification	Alcoa No. (a)	Cu	Si	Mn	Mg			Ave.	Min.	Ave.	Min.	Ave.	Min.								
									Work Hardening Alloys (f)													
25	B 25-42 T	2s O					99 Al	1/16" Sheet	13 (15.5 max)		5		35	30	23	9.5	5	A	B	2s O		Commercial Al; Good Forming Properties
	B 25-42 T	2s ½H						" "	17	16	14		9	6	32	11	7	B	B	2s ½H		Good Corrosion Resistance, Low Yield Str.
	B 25-42 T	2s H						" "	24	22	21		5	4	44	13	8.5	F	B	2s H		Cooking Utensils, Sheet and Tubing
29	B 29-42 T	3s O			1.2			" "	16 (19 max)		5		30	25	28	11	6	A	B	3s O		Similar to 25
	B 29-42 T	3s ½H						" "	21	19.5	18		8	7	40	14	9	C	B	3s ½H		Slightly Stronger and Less Ductile
	B 29-42 T	3s H						" "	29	27	25		4	4	55	16	10	G	B	3s H		Cooking Utensils, Sheet Metal Work
201	B 109-42 T	52s O				2.5	Cr 0.25	" "	29 (31 max)		14		25	20	45	18	17	A	B	52s O		Strongest Work Hardening Alloy
	B 109-42 T	52s ½H						" "	37	34	29		10	7	67	21	19	D	B	52s ½H		High Yield Strength and Fatigue Limit
	B 109-42 T	52s H						" "	41	39	36		7	4	85	24	19	G	B	52s H		Highly Stressed Sheet Metal Products
									Precipitation Hardening Alloys (g)													
26	B 78-42 T	17s O	4		0.5	0.5		" "	26 (35 max)		10		20	12	45	18	11	B	E	17s O		Dunalumin. Most Common Strong Alloy
	B 78-42 T	17s T						" "	60	55	37	32	20	18	100	38	15	H	D	17s T		Hardened by Quenching and Aging
	B 78-42 T	17s RT						" "	65	60	47	52	13	10	110	38		J		17s RT		Available in Most Wrought Forms
		Alclad 17s T	(Coated with 99.75 + Al)					" "	56	50	33	28	18	16		32		I	A	Alclad 17s T		Alclad Has Best Corrosion Resistance
		17s T						Forging	60	55	30	30	16	16	100	36	15		D	17s T		High Strength Heat Treated Forgings
		A 17s	2.5			0.3		½" Rod	43		24		24		70	26	13.5	F	D	A 17s		Best Forming Properties. Rivets
24		24s O	4.6		0.6	1.5		1/16" Sheet	26 (35 max)		10		20	12	42	18	12	B	E	24s O		Strongest Alloy for Rolled Forms
		24s T						" "	68	62	44	40	19	17	105	41	18	J	D	24s T		Used Widely in Aircraft Construction
		24s RT						" "	70	69	55	52	13	12	116	42		K	D	24s RT		More Difficult to Form Than 17s
		Alclad 24s T	(Coated with 99.75 + Al)					" "	62	56	41	37	18	14		40		J	A	Alclad 24s T		High Strength Alclad; Corr. Resistance
281		61s W	0.25	0.55		1.0	Cr 0.25	" "	35	30	21	16	22	16	65	24	12.5	F	C	61s W		Good Forming Properties. High Yield Str.
		61s T						" "	45	42	39	35	12	10	95	30	12.5	G	C	61s T		Will Not Age Harden at Room Temp.
		53s W		0.7		1.3	Cr 0.25	" "	33	28	20	16	22	17	65	20	10	F	B	53s W		Good Forming Properties and
		53s T						" "	39	35	33	28	14	10	80	24	11	G	B	53s T		Corrosion Resistance
280		A 51s T		1.0		0.6	Cr 0.25	Forging		44		34		12	90	32	10.5		C	A 51s T		For Intricate Forgings
27		25s T	4.5	0.8	0.8			"		55		30		16	100	35	15		E	25s T		Good Forgeability. Lower Cost.
		14s T	4.4	0.8	0.8	0.4		"		65		50		10	130	45	16		D	14s T		Strongest Forging Alloy
		70s T	1.0		0.7	0.4	Zn 1.0	"		50		40		16	85	37	21		F	70s T		High Endurance Limit
		18s T	4			0.5	Ni 2	"		55		40		10	100		14.5		E	18s T		Strong at Elevated Temp.; Forged Pistons
		32s T	0.8	12		1.0	Ni 0.8	"		52		40		5	115	38	14		C	32s T		Forged Aircraft Pistons. "Low-X"
		11s T3	5.5			(Bi 0.5)	Pb 0.5	½" Rod	48	45	42	38	14	10	100	30	12.5		E	11s T3		Free-Cutting Screw Machine Products

Sand Casting Alloys

S.A.E.	A.S.T.M. (B 26-42 T)	Alcoa	Cu	Si	Fe	Mg	Zn	Condition	T.S. (b)		Y.S. (b)		Elongation		B.H.N.	Shear	Endur. (c)	Impact	Corr. (e)	Alcoa	
56	CS 21	212	8	1.2	1			As Cast	22	19	14		2	0	50 to 70	20	7.5	0.6	D	212	General Casting Alloy. Not Heat Treated
53	CS 22	112	2.5		1.2		1.5	" "	22	19	14		1.5	0	55 to 80	20	8	0.6	D	112	Good Casting Properties
31		645	2.8		1.2		11	" "	29	25	22		4	2.5	70	22.5	25	2	D	645	General Casting Alloy
55	S 2	43		5				" "	19	17	9		6	3	35 to 50	14	6.5	1	A	43	Thin, Pressure Tight Castings. Corr. Res.
32	S 3	47		12.5	(Trace Na)			Modified	26	24	11		8	5	45 to 60	18	6	3	A	47	Alpax or Silumin. High Strength, Elong.
38	C 1 HT 1	195 T 4	4					Soln. H.T.	31	29	16		8	6	55 to 75	24	6	2.8	C	195 T 4	High Strength Heat Treated Castings
38	C 1 HT 2	195 T 6	4					H.T.	36	32	22		4	3	70 to 90	30	6.5	1.8		195 T 6	Aircraft, Marine, Bus,
38	C 1 HT 3	195 T 62	4					H.T.	40	36	31		2	0	80 to 100	31	7	1.5		195 T 62	and Engine Parts
		A 334	5	4		0.3		As Cast	26	22	16		1.5	0	65	24	8.5	0.2	B	A 334	Intricate Castings
322-1	CS 21 HT 1	355 T 4	1.2	5		0.5		Soln. H.T.	30	26.5	20		5	3.5	50 to 65	28		1.3	A	355 T 4	Liquid Cooled Cylinder Heads
322-2	CS 21 HT 2	355 T 6						H.T.	35	32	25		3.5	2	65 to 85	30	8.5	1.1		355 T 6	Intricate Castings
322-3		355 T 61						H.T.	38	35	33		1	0.5	80 to 95			0.8		355 T 61	Good High Temperature Strength
	CS 21 HT 3	355 T 51						H.T.	28	25	23		1.5	0	50 to 70	22	6.5	0.2		355 T 51	Water Jackets, Exhaust Manifolds
323-1	SG 1 HT 1	356 T 4		7		0.3		Soln. H.T.	28	26	18		6	5	50 to 70	22		1.7	A	356 T 4	Intricate Heat Treated Castings
323-2	SG 1 HT 2	356 T 6						H.T.	32	30	22		4	3	60 to 80	27	8	1.0		356 T 6	Good Corr. Resistance, Pressure Tightness
320	G 1	214				3.75		As Cast	25	22	12		9	6	40 to 60	19	5.5	3.6	A	214	" " " Impact Toughness
324		220 T 4				10		Soln. H.T.	44	42	25		14	12	70 to 85	33	7	4.5	A	220 T 4	Highest Impact Toughness (h)
34	CG 1	122	10		1.2	0.2		As Cast		18.5				0					D	122	Common Piston Alloy. Wear Resistance
34	CG 1	122 T 2						Soln. H.T.	25	23	21		1	0	75	25.5	9.5	0.7	D	122 T 2	High Temperature Strength
34	CG 1	122 T 61						H.T.	36	30	30		1	0	100	29.5		0.68	D	122 T 61	Also Permanent Mold Castings
30	CN 21	142	4			1.5	(Ni 2)	As Cast	28	25	24		1	0	80	24	8	0.6	C	142	High Temperature Strength and Stability
39	CN 21	142 T 61						H.T.	37	32	32		0.5	0	100	32	8	0.6	C	142 T 61	Also Permanent Mold Castings

(a) Aluminum Co. of America Alloy No. & Heat Treatment Designations: O = Annealed, W = As Quenched, T = Quenched & Aged, H = Cold Rolled to Hard Temper; ½H = Half Hard Temper, R = Cold Rolled After Heat Treatment, S = Wrought Alloy.

(b) In Thousands of Pounds per Square Inch. Yield Strength Taken at 0.2 % Permanent Set.

(c) 500 Million Cycles in Reverse Bending.

(e) Relative Resistance to Salt Water Corrosion; A = Best

(f) Can Be Hardened by Cold Work Only.

(g) " " " " Heat Treatment

The clever cartoons, "shop drawings" of important figures in the world scene, printed on page 961 of the November issue, were secured from American Machinist, whose editor did not know the artist's name. We now gladly state that the gifted man is Charles Carew, sometime of Canadian General Electric's Peterborough (Ontario) Works, now of the Royal Canadian Air Force

Critical Points

By the Editor

IMPRESSED vividly in visiting Tubular Alloy Steel Corp. with the contrast between small area required for a hot piercing mill and the acres occupied by annealing furnaces, pickling tanks, draw benches, cut-off machines, testing, inspection and shipping departments. It's apparently easy and fast to make the raw material; relatively difficult and slow to finish it. (This effect is multiplied to the *n*th degree in aircraft fabrication — witness a recent WPB boast that the "average monthly airframe weight output per employee is now 60 lb.")

Aircraft tubing in infinite variety

Tubular Alloy Steel occupies enormous buildings erected in the 1920's by National Tube Co. near the Gary steel mill, and recently re-equipped by Defense Plant Corp. Its principal output is thin-walled aircraft tubing in small sizes (typically 1 by 0.065 in.) of X-4130 and NE8630, although the range is ⅛ to 8⅝ in. o.d. Important production of 52100 tube in large diameters and thick walls for ball bearing races is also under way. Throw in a sizable tonnage of 18-8 stainless tubing and 5% chromium steel tubes for petroleum stills and you can visualize the complicated housekeeping problems involved, and also understand the great variety of furnaces installed for heating and intermediate operations. From billet yard to shipping dock, all material must be properly segregated and identified, not only by analysis but heat number. Whenever there is a suspicion that any mix-up has occurred in the dozens of handlings before final inspection, the spark test and spot test are repeated 100%. Inspection of each tube electrically — or should I say "electronically"? — by comparison against a known standard in equipment like the "identometer" is also frequent, so insistent is everyone on production being true to type.

The technical staff was much concerned over the fact that the fuel available — by-product coke oven gas — carried as much as 250 grains of sulphur per 100 cu.ft. Such fuel would undoubtedly sulphurize the surface of hot billets. Fortunately the Koppers-Seaboard process is available, whereby most of the sulphur-containing compounds are washed out with sodium carbonate solution, the solution being rejuvenated very simply by aeration. Gas coming from these washing towers contains about 7 grains sulphur per 100 cu.ft., and is quite all right for fuel gas in non-muffled heating furnaces. A relatively small part is used in DX units for preparing bright annealing atmospheres; this gas is passed through trays of iron sponge, and sulphur is then reduced to an amount lower than carried in most natural gas.

Taking sulphur out of fuel gas

Here, as at all plants recently visited in the Chicago region, women have invaded men's traditional preserves. At Tubular Alloy, they make up at least one-third the employees in all departments except the hot mill. One expects to see female inspectors, and even tructractor drivers, but wouldn't old Rule O'Thumb turn over in his grave at the thought of a woman drawbench operator? Such of these women as still manage homes, and clean pots and pans, can understand why steel wool is so scarce — it's used to plug ends of tubes and protect the inner surfaces during process anneals.

NOTED MANY CHANGES, when revisiting the mammoth Gary mill of U. S. Steel Corp. (Carnegie-Illinois), some of which may be merely signs of the times, such as a half-empty ore dock even though the ore boats are about to be frozen in for the winter. Women, women everywhere, from gardeners on the general office lawn to metallurgical observers on the openhearth floor, crane-women moving soaking pit covers, pyrometer operators in blooming mills, and even grinders in the plate mill!

An item of more technical importance is the increased attention given to ingot practice, and methinks it smart to spend a dollar in making an ingot sound in heart and skin and save two dollars in remelting rejects and on chipping labor.

Improved ingot practice at Gary

Mold preparation now has a complete big building of its own, where molds are inspected, cleaned and tarred, and hot tops lined, preheated and set. "Basket pouring" is also practiced, wherein a small ladle is interposed between main ladle and molds; the small one is kept practically full at all times, and two streams teemed from stoppered nozzles into a pair of molds. Splash is thus avoided and ingots can be cast more slowly and at a uniform rate, no matter whether they are first or last of the heat. Even more important for alloy grades requiring exceptional cleanliness is the ability to tap at maximum temperature and pour at a reduced temperature, thus improving the cleanliness of the steel.

The old, rather small soaking pits have been generally replaced by cavernous Swindell-Dresslers or Amsler-Mortons, each one big enough for a 200-ton heat of square or slab ingots. My guide, ART BEERS (formerly chief plant metallurgist but now engineer in charge of quality control), and I talked long with the heater at the 44-in. mill, and concluded that rapid delivery of properly heated metal to the blooming mills required the artful placing of ingots in pits, paying attention to the ingot size, composition, and surface and center temperature, to say nothing of the sharpness of the pit operation. However, we could hit upon no reasonable explanation of the fact that when a pit is uncovered and the interior gradually clears so the eye can mark its contents, the very top surface of the ingots quickly darkens, appearing almost stone cold amongst the glowing surroundings.

In the 44-in. bar mill, the rollers were blooming 30 by 48-in. ingots in tandem. This is a reversing mill with rather slow screw-down; likewise, it has approach tables of ample length. Thus the tonnage is increased on the order of 10%, or 20 tons per hr.

At the busy rail mill we recalled that Carnegie-Illinois' JOHN BRUNNER spent a lifetime in studying tough steels for railroads, and was responsible for a simple and thoroughly efficient method of preventing internal shatter cracks, so dangerous in rails. The scheme merely is to slow-cool the rails from 900° F. to below 300° F., taking say 15 hr.

Cooling pits on wheels

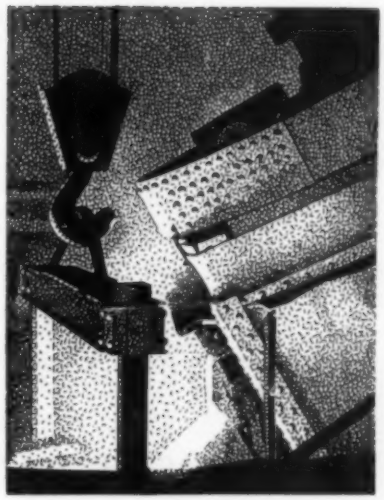
But where, in a closely built mass of buildings like Gary, could enough space be found for pits or furnaces to hold 3000 tons of rails, the mill's capacity for two shifts? His mind turned to the transportation system, the 300 miles of standard gage tracks inside the fence. Forthwith, long lines of steel gondola cars were brick lined and tightly covered; presto, a battery of furnaces on wheels! (MEMO to those who still ride railroads and like to keep track of speeds: The standard rail length for main lines is now 39 ft. instead of the old 33 ft. So, in counting wheel clicks for miles per hour, count the number in 26½ sec. rather than in 22½ sec.).

HAPPY to be able to inspect — under able guidance of ANDY FORREST, assistant chief metallurgist — Republic's new electric steel plant adjoining the old cold-melt openhearth plant in South Chicago. (In that sentence the word "Republic" has a double meaning; the Government owns the plant and the Corporation operates it.) Completely integrated from ore dock, blast furnace, and coke plant, the melt shop can be independent of purchased scrap, replacing it with molten basic pig. Phosphorus, silicon and most of the carbon is eliminated from all pig or pig-scrap charge, depending on the available supply, in a battery of four 250-ton tilting openhearths. When carbon is down to 10 points above that specified in the finished steel, the openhearth is tapped and the metal transferred in 100-ton ladles to waiting electrics, of which there are nine. In this way the electric furnace is relieved of the costly melt-down period; ore and lime and some own mill scrap are also charged so there is an efficient boil and a good oxidation period in the hot, fluid steel in a hot furnace; then follows the manganese reboil, slag-off, and the final refining stage under carbide slag. The practice was developed by BILL FARNSWORTH at Republic's Canton (Ohio) plant, where stationary openhearths are used for melters. Six hours, tap to tap, is the schedule.

Completely integrated electric steel mill

Notable features, and reasons therefor:

High roofs, overhead clearances and floor-to-pit dimensions, producing a spacious shop, clean and smoke-free, are the result of designing for gun steel production. Guns need unusually long ingots, so soaking pits, mold preparation buildings, casting platforms, crane clearances — all have to be appropriately deep.



Tremendous area given over to cooling pits and furnaces. All the blooming mill product must be slow-cooled, and the bar mill product as well. The time is about seven days, so there must be cooling capacity for 25,000 tons of steel in each of the two departments. Result: Long lines of car-bottom furnaces; an even larger number of deep, brick-lined pits, covered and steel armored; and acres of shallow, slag-filled bins above ground.

Mechanical handling of materials in the testing and inspection departments. 100 tons of metal — some pieces as big as 20 in. square by 3 ft. long — go through the laboratories *every day*, and 70% of the work in the laboratory is done by women. Hence rugged conveyors and overhead cranes and tramways carry the loads to furnaces, saws, lathes and other sample-preparation units.

HEAD AWHIRL at the complexity and immensity of Chrysler Corp.'s "Dodge Chicago Plant", just getting into production of 18-cylinder Wright Whirlwind motors — complex because nearly all parts, even auxiliaries, are to be made here rather than by distant sub-contractors, and immense because of the eventual output of these engines. It's a mile and a quarter from forge shop to office, and the main building is so large the supervisors travel in baby automobiles.

Diverse plating & de-plating

The chief metallurgist,* has among other duties to supervise the central laboratory (as large, diverse and well equipped as ever I did see) plus separate inspection and control laboratories, one in the forge shop, another very large one for analytical, sand control and X-ray inspection in the aluminum and magnesium foundries, another in the main heat treating department, and another for the pyrometry division.

*Well known as the originator of the end-quench system of measuring hardenability.

In the plating department, as in all others at Dodge Chicago, there are individual line-ups for practically every job, and few all-purpose machines. Hence the equipment seems unusually generous but even though expert help could be secured, it doubtless pays dividends to keep every operation separate and under close technical control, especially when plating air engine parts whose acceptance limits are so rigidly enforced. There is tin plating to stop-off nitriding, copper plating to stop-off carburizing, de-plating to save both critical metals, silver plating for bearings (and a thick, tight, smooth, crack-free silver deposit is the hardest job in the repertoire), cadmium and zinc for rustproofing, copper and nickel for underplates, and chromium for wear resistance. Then too there are chemical surface treatments — phosphate coatings on steel, anodizing of aluminum, impregnating of magnesium castings, and chromate pickling of both the light metals. All in all, a rare man is necessary to supervise such a melange.....

The forge manager took pardonable pride in many features in his division — and "division" is the right word, for it comprises four very large units: Power house, heavy forge, light forge, and die shop. It's as clean as a pin, thanks to scale catchers and high well-ventilated roofs. Principal forgings are of high nickel-chromium 3312 and 3340 steels; sizable ones are cooled in slag pits dug into the floor. Three of the largest forging machines I ever did see are upsetting and piercing cylinder barrels of nitralloy, the heavy billets being heated in pairs of long slot furnaces, one to right, one to left, conveyorized with traveling chain belts along the front. All forge furnaces are oil fired, and much use is made of the rotary type, wherein the heating rate is as high as 15 min. per in. thickness.

Forging and heat treating 3300 steels

Die shop is much more than the name implies, for it also holds a dozen lines of continuous furnaces and hundreds of machine tools for rough machining cylinder barrels and crank cases. The furnace lines may have two furnaces in tandem for quench and draw, or there may be three-in-line for such a cycle as: Normalize, air quench, reheat, oil quench, draw, air cool. The superintendent of heat treating operations quoted the following schedule for 3312 forgings, which

will nearly always eliminate banded structure: Heat to 1725° F. in 2 hr., hold 1 hr., air blast cool to 1000° F., reheat to 1100, hold 4 hr., air cool. Resulting forgings then Brinell 217 to 241, although gears machine better when slightly harder.

This furnace line-up at the forge shop is a respectable installation itself, but is dwarfed by the main heat treat, whose scale may be judged by the nitriding section, which alone contains 64 bell-type furnaces. Lines of over-sized carburizing furnaces range down both sides of a craneway, built mostly below grade so their tops are about 3 ft. above floor line, thus being easily manipulated, yet safe. Since quenching from the carburizing heat is not permissible, each pair of carburizers has three covered cooling cylinders, so there is no long delay and waste of heat while a carburizing furnace and load would cool.

Continuous mill for aluminum sheet

So MANY SIMILARITIES exist between Alcoa's continuous aluminum sheet mill and the huge continuous mills built five to ten years ago by the steel industry throughout the Central West, that the EDITOR is impelled to paraphrase closely a "Critical Point" written years ago after a visit to the then new Irvin mill of Carnegie-Illinois, and say:

"To the Chicago Works near Brookfield which Aluminum Co. of America has just finished for Defense Plant Corp. It exhausts the superlatives of any except those who have already seen several of these tremendous sheet mills, and even such observers must express their admiration of some aspect of it or the manifold auxiliaries and finishing departments, capable of doing by the ton what the outmoded hand mills did by the pound. Not least amazing is EDWARD MAZIARZ's unseen organization which constructed this multi-million dollar machine in 12 months. Granted that the buildings and equipment almost duplicate two other sheet rolling plants, and that the work was done by hundreds of contracting firms — still an admirable staff must have cooperated admirably from first to last."

Employee hiring but particularly training must involve manifold problems connected with making skilled metal workers out of laundry wagon drivers, beauticians, farm hands and high schoolers. So you are not surprised to see a slip of a girl sitting in a pulpit alongside the great brute of a blooming mill, single-handedly operating all the controls for taking an 8-in. ingot down to a 2½-in. slab. (That's always the way with women, even before Delilah broke into print!)

This plant has a large melting department not found in corresponding steel mills, which ordinarily receive their ingots or slabs from another place. The furnaces are coal-fired reverberatories, wherein aluminum pig, secondary and own scrap are melted with the appropriate alloys. The hearth of these furnaces is double — that is, the portion near the fire bridge is separated by a low partition from a deeper area known as a "cracker box". The properly melted, alloyed and refined metal in the hearth is siphoned over the partition into the cracker box where it can be held to 25° temperature tolerance during the continuous casting process. Continuous chill-casting is very trick; a small stream of molten metal enters a shallow water-cooled pouring box whose inside dimensions equal the width and breadth of the ingot. This box has no bottom — or rather, the bottom is the metal already solidified, and this solid portion slowly lowers by hydraulic ram at the same rate the liquid metal runs in, until the 10-ft. length is built up.

Chill-casting of slab ingots

In various wings or bays leading off from the main aisle housing the hot rolling mill an inordinate number of furnaces are found, seemingly necessary for heating, reheating and heat treatment, the large number mostly due to the fact that the temperatures are low rather than high! The optimum temperatures are so close to the melting point that a high heat-head between source and work would cause ruinous local overheating, and so it takes time to get the metal uniformly up those last few degrees. This low temperature is also a prime factor in another striking difference from steel mills, namely, absence of smoke, steam and mill scale. Everything in a new mill is of course clean, but it undoubtedly will be kept so, because the extraordinarily rigid inspection for slight scratches on finished product demands the best of housekeeping.

How to heat mildly but accurately

Quenching is also an operation seldom found in a steel mill. Alcoa's furnaces for this are also specialized, being built on stilts with quick-opening bottoms for doors. Some 40 to 50 sheets are hung from an overhead rack so each is free from its neighbor, the rack is hoisted into the furnace, the furnace closed, the charge is heated uniformly, and at a given signal the entire furnace bottom opens up, and its charge drops in a split second into a sub-floor quenching tank immediately below.

One of the important steps whereby we were able to stretch out our limited amount of ferro-alloy over the enormous amount of war-time steel was the formulation of the National Emergency steels. A capacity audience at the ⊕ Convention listened to the several talks on this subject, including the following, principally on the steps leading up to the acceptance of NE steels by the Armed Services

Production, Utility and Acceptance of the NE Steels

The Alloy Situation

Foreword by The Editor

IT WOULD BE tedious to recount the ups and downs in the ferro-alloy situation since the United States entered the war, nor are actual figures on production and stock-piles available or publishable if known. It is no secret, however, to state that as of today, the American situation is far easier than at any time within the past two years; in fact, stocks are actually on the increase, even if slowly. This happy state of affairs has been brought about *(a)* by increasing the importation and local production of ores; *(b)* by changing from higher alloy to lower alloy or heat treated carbon steels where possible, and *(c)* by devising new compositions or National Emergency steels needing nothing much more than the alloy contained in the circulating scrap. (The chairman of the ⊕ Group Meeting on National Emergency Steels reported below, H. LeRoy Whitney, was the prime instigator of the last move.)

Nevertheless, it is no signal for relaxing efforts to conserve; if the metallurgical history of the last two years teaches anything it is that nothing can be counted on except change. We are even now in a position where carbon steels, and prime carbon steel scrap, are more urgently needed than alloy steel.

Nickel was the first alloying metal to be put under strict governmental control. Factors that have tended to alleviate the early shortage are: *(a)* Increase in new nickel available; the United Nations now control 95% of the world's supply, and currently three to four times as much is available for steel manufacture thar in the year of peacetime peak consumption. *(b)* Large absorption of nickel alloy steel in process is no longer necessary, now that the floating load is roughly stabilized. *(c)* Alloy steel scrap is better segregated, so more nickel gets back into use. *(d)* Uses of high chromium-nickel steels have been restricted, and alloy contents cut to the bone. *(e)* Much nickel has been recovered from alloy scrap. It results that the present situation in nickel may be characterized as "comfortable".

Molybdenum — When nickel got short in 1941 there was a rush to molybdenum steels, so it also got scarce. Fortunately the element does not slag off in remelting, and great economies have resulted from the intelligent formulation and wide use of the NE steels, as outlined by Mr. Parker below, so that by mid-'42 the production slightly overbalanced consumption, and stocks are now increasing gradually. It has been officially stated that in August 1943 the unused stock amounted to 23,791,000 lb. of molybdenum metal, estimated at about six months' production and eight months' needs.

Manganese and chromium have been handled

largely by intelligent planning of imports, together with noteworthy additions from American mines (see *Metal Progress* for August 1941, and March and April 1942). Both these elements have been conserved by methods *(b)* and *(c)* in the first paragraph, with the result that sufficient chromium has been available for the unprecedented amount of heat and corrosion resistant alloys needed for the war effort, and our reserve position is still unimpaired. Chromium is so easy in present supply that the new source of ore in the Absoraka mines in Southern Montana is no longer being vigorously developed.

Vanadium is now being produced in America at a rate (estimated by *Wall St. Journal*, Dec. 13, as 5,700,000 lb. of metal) close to four times the 1920-1940 average. Half of the requirement is for high speed tools. A large part of the remainder goes into armor plate and armor piercing shot. At one time vanadium was excluded from many varieties of toolsteels, but these restrictions are being gradually lifted — now that the tooling program is being completed — and it is possible that some vanadium may soon get back into chromium-vanadium constructional steels, or into "intensifiers" or "reaction alloys" for increasing hardenability and toughness of the mild carbon and carbon-manganese steels. The above-quoted source estimates 1943 consumption at approximately 3,500,000 lb.

Aluminum for deoxidizing and for grain size control was once very short. At present there is a large amount of metal available, high in iron and silicon, produced during shake-down operation of the new aluminum plants. Likewise more and more impure aluminum from crashed aircraft is being remelted, but this is contaminated not only by the copper, manganese and magnesium hardeners of the strong alloys themselves, but magnesium and zinc from die castings, chromium and iron from stainless parts, lead and tin from bearings. Such reclaimed material can be used for killing high grade alloy steels, but only with the greatest circumspection. Such secondary metal is indeed such a drug on the market that ceiling prices have been reduced 1.5¢ per lb.

The Future — Repeatedly in the Group Meeting to be reported speakers emphasized the fact that alloy shortages which led to the emergency steels resulted from the unprecedented demand for alloy steels in comparison with plain carbon steels, many times the normal ratio, and by that same token led to a great increase in the amount of alloy-bearing scrap. This scrap situation will probably obtain for ten years or more after we stop making munitions at break-neck speed, and will prevent the ready production of binary alloy steels such as Cr-Ni, Cr-V, and the single alloy steels of the manganese, molybdenum, and nickel types.

This may not be much to cry about, because specification of steels on a hardenability basis often leads the steel maker to put in more alloy as insurance than is really necessary. Another circumstance that will require more and more alloy will be the trend in mobile equipment toward low weight, highly stressed parts which automatically require liberal alloy content. Both of these needs are well met by the Ni-Cr-Mo types so desirable to absorb available scrap. Finally, another speaker pointed out that lower alloy steels were finding increasing application where heat treatment is of a type to overcome low hardenability — that is, where atmosphere-controlled furnaces or induction hardening are used and the quality of the quench is better.

It results, therefore, that wholly aside from the inherent excellencies of the NE or triple alloy steels, economic and collateral considerations will urge their use for many years to come.

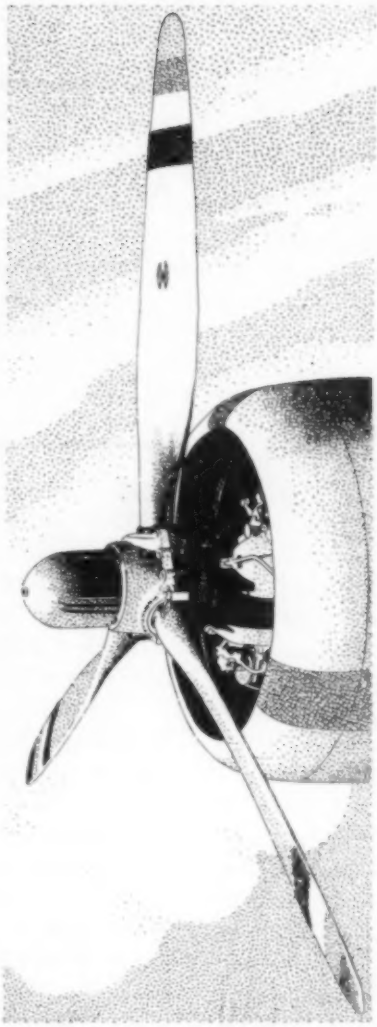
General Production and Utility

By Charles M. Parker
Secretary, General Technical Committee
American Iron & Steel Institute

It is now some 20 months since the original lists of National Emergency steels were presented to users. Since that time, we have seen history made not only on military battlefields but on the home front — in the laboratories and rolling mills, and on the thousands of production lines which draw their life blood from alloy steel.

In total war it is said that each individual in the belligerent camps has a direct job to do in defeating his enemy counterpart. There can be no doubt that the designers, metallurgists and heat treaters of America have defeated their Axis opponents — and one of their major weapons has been the National Emergency steels.

Nearly two years ago you were told that there was a serious shortage of both strategic and critical alloying elements; that because of that shortage you would have to do more of your jobs with smaller amounts of alloys or different alloy steels than you had been used to using.



Some of you responded immediately and in such a manner that it is now safe to say that wherever a United Nations soldier moves into combat, NE steels move with him. Others of you were a little slow to accept the new steels but, as time went on, old prejudices were forgotten and the new materials were accepted.

Even as our thinking underwent changes, the situation as respects alloying elements changed, too. Severe shortages were relieved, but the handling of scrap at points of fabrication and at collection depots left something to be desired. Reserve alloy contained in scrap became more and more a combination of the three elements, nickel, chromium and molybdenum. It became virtually an impossibility for the steel industry to produce a nickel-chromium steel without molybdenum, a nickel-molybdenum steel without chromium or a chromium-molybdenum steel without nickel. The third element was most often present in sufficient quantity to alter materially the hardening characteristics of the steel. That alteration was not taken into account by designers. Therefore, the maximum potentiality of the steel was not employed and a substantial quantity of alloying elements was wasted. Those conditions made the increased use of nickel-chromium-molybdenum steels mandatory for the success of our war effort.

As the production lines sent forth their ever mounting streams of matériel, the quantity of alloying elements contained in scrap rose ever higher and scrap collections brought in thousands of tons of old, rich alloy steels. Moreover, large quantities of high alloy scrap were generated in steel mills producing great quantities of products which had, because of some necessary special characteristic, to be made of high alloy steels, and which also, by the nature of the product, yielded a low percentage of the ingot in up-to-specification forms. For those reasons, the nickel and chromium contents of some of the earliest NE steels had to be adjusted upwards.

In spite of the splendid performance record of those steels, there are many plants which do not yet use them. Believe it or not, within the last two weeks, we received a letter from the chief metallurgist of a very large producer of armament equipment in which he stated that he understood there were such things as NE steels and wondered where he could get information about them!

At the present time and for the past two or three months, the alloy constructional steel melt has largely been composed of two grades of single alloy steel, three grades of binary alloy steel and four grades of nickel-chromium-molybdenum or triple alloy steel. The quantity of alloy elements contained in scrap is now such that it is desirable to raise the tonnage of the triple alloy steels in the 4300, 4720,* 8600, 8700 and 9400 series to a larger proportion of the total melt. About one-quarter of the alloy constructional steels cannot be changed because they must possess special characteristics not inherent in any of the triple alloy steels. One class of binary alloy steel is so economical of alloying elements contained in scrap that no change is necessary or desirable. But another large group of steels, the characteristics of which are no different from the characteristics displayed by the NE steels, must be changed over to the triple alloy group not only to conserve alloying elements but to utilize the iron units and, by permitting proper leeway in scrap economics, to conserve other critical raw materials and time in melting, and to reduce the load on already overtaxed transportation facilities.

The present production volume status of the triple alloy steels shows the 9400 series leading the field, with the 8600, 4300, 8700 and 4720 series following in that order. Within those groups, individual compositions have come to the fore. In the 9400 series, 9440 leads by a very wide margin. In the 8600 series, the honors are about equally divided between 8620 and 8630. In the 4300 series, 4340 stands almost alone and in the 8700 series, 8720 comprises 100% of the tonnage (indeed, it is the only one of the 8700

*A steel accepted by the Roller Bearing Engineering Committee with the following range: 0.17 to 0.22% carbon, 0.90 to 1.20% nickel, 0.35 to 0.55% chromium and 0.15 to 0.25% molybdenum.

steels retained in the latest list of standard compositions). Briefly, we find a very high percentage of the total alloy constructional steel melt being represented by two carburizing grades and by three semi-thorough hardening grades. In the tractor industry, for example, two NE carburizing grades carry nearly all the load.

It is not surprising that such a condition should exist in steels which are put to use in the heat treated condition. A forceful argument is that when steel is put into many uses, the microstructure is more important than the chemical composition provided sufficient alloy is present to make heat treatment effective in depth. And the fact that these NE steels do so well the jobs passed on to them by the higher alloy steels is a tribute to the heat treaters upon whom has fallen the responsibility of seeing the job through.

I do not mean to give anyone the impression that it has been a very simple thing to solve many of the problems which have confronted you. I think that everybody in the steel industry who is in any way connected with the manufacture and use of alloy steels knows that some of you have had difficult times in adjusting heat treatment practices and controls to fit the personalities of these new steels. You have done it so well that, to the best of my knowledge, there no longer arise such questions as: "Are the NE steels strong enough, or tough enough?" The principal question that now confronts you is, "Which of the grades presented shall be selected to solve the problem with the equipment with which I have to work?"

I do not want to imply either that the NE steels have licked every problem presented. Some compositions have failed to come up to expectations — some have far exceeded expectations. But we are certain that, properly applied, the outstanding grades in each of the series previously mentioned will be tough to beat. They have been tested not only in the laboratory but in the field. Some of them have had the honor of chasing Rommel across Africa, others drove our landing barges ashore at Salerno, Attu and Guadalcanal, and still others ride the clouds in every theater of war.

The exact quantities of each grade produced cannot now be divulged but while you have been reading this brief note, two heats have been tapped. To finish our job as quickly and efficiently as possible, we should raise that to three.

If any of you are not making maximum use of nickel-chromium-molybdenum steels, again look over your application schedules, talk with those who are using them, bear heavily on their experience, and shift part of your load.

Acceptance by Army Ordnance

By Lt. Col. John H. Frye
Office of the Chief of Ordnance
War Department, U. S. A.

THE WAR DEPARTMENT was one of the first organizations in industry or government to recognize the potential value and use of NE steels. As early as March 1942, or by the time the compositions of such grades were generally known, a selected number of them were included in U. S. Army specification for bars, 57-107.

NE steels included in Army specifications are designated as "WD", for War Department. It will be recognized that the composition of steels used for war matériel must be controlled by the War Department, otherwise it would be possible for the compositions to be revised or even eliminated without the knowledge of the engineers responsible for the construction and functioning of the matériel. The composition and characteristics of WD "lean alloy steels" correspond almost identically with those shown under NE designation.

Steels such as 4000, 8600, 8700, 8900, 9400 and 9500 series have been incorporated in bar, tubing, sheet, and plate specifications, and have been used extensively as substitute materials in Ordnance matériel, both in existing items and in new designs.

The Ordnance Department of the Army is the largest single claimant agency for steel, and particularly for alloy steels. This steel is purchased by two methods: First, that which is specified by contract or specifications, and second, that which enters into the production of items purchased on a performance basis. Steels which are specified are controlled by the Ordnance Department, but steels used in making items purchased on a performance basis are under the control of the manufacturer.

Substitutions of lean alloy steels for higher alloys, in instances in which the Ordnance Department specified the grade of material, were based on technical information developed and furnished as rapidly as each step was completed by the cooperating committee of the American Iron & Steel Institute. In some instances further laboratory or service tests were made. However,

there remained a large tonnage over which Ordnance had limited control, such as steels entering into trucks, certain components of tanks and similar items. It will be recalled that it was nearly impossible to obtain small quantities of these grades for test purposes, and consequently the manufacturers were unable to prove to their satisfaction that these lean alloy steels would meet requirements. Without this knowledge, it was impossible for them to guarantee performance. This condition continued until the Ordnance Department inaugurated a cooperative test program, for the purpose of supplying test quantities of these newer steels to its contractors. The Society of Automotive Engineers' War Engineering Board appointed a special subcommittee to coordinate this work in the automotive industry. Arsenals, industry integrating committees, and interested manufacturers participated to a similar extent in this arrangement, for the use of these steels in tanks, automotive vehicles, artillery, small arms weapons and other war matériel was involved.

It was desired to provide each manufacturer with sufficient metal for test purposes, thus allowing him to judge its suitability for his particular applications. In addition to this personal or company experience, it was further desired to coordinate the experiences of various manufacturers making similar articles. Thus each manufacturer would not only have the benefit of his own experience, but would also have available the experience and opinions of other users and fabricators. It was believed that such an arrangement would permit more rapid adoption of the lower alloy grades. Consequently each of the interested agencies was requested to list the sizes and grades desired for test by the various participants within that agency. Later, a compilation of the sizes and grades of these agencies was made, and officers were assigned the problem of seeing that each manufacturer received his material. The War Production Board cooperated to the fullest extent; in many instances, the desired material was frozen in commercial warehouses, and could not be delivered except to specified companies.

As an example of the magnitude of this

Land Battleship With Welded Armor, Charging Headlong. Official O.W.I. Photo

program, there was a total of 370 different sizes, involving 187¾ tons of alloy steel distributed in small quantities, usually less than 1000 lb. The sizes ranged from $\frac{5}{16}$-in. round to 4 by 7-in. billets. Squares, rounds and hexagons were requested in hot rolled and cold drawn conditions, and there were a number of requests for billets to be forged into parts and subsequently heat treated.

Through the splendid cooperation of the W.P.B. and each of the interested manufacturers, this material has long since been delivered. Some service tests are still being conducted; in many other instances reports have been received indicating that the lean alloy steels were not only satisfactory but have been adopted for production work. Only for a limited number of applications were these steels found unsatisfactory, primarily 9400 grades for highly stressed gears.* There were literally hundreds of test programs on a smaller scale, usually with the objective of approving individual items.

Many of you gentlemen know of the extensive test work done to determine the suitability of these triple alloy steels for the production of ballistic items. W.P.B.'s Conservation and Operating Committee cooperated with Ordnance, and a large number of heats have been made and fabricated into armor piercing shot and bullet cores. These were tested at the proving grounds, and adjustments in composition and heat treating have been made until the Ordnance Department is convinced that satisfactory ballistic properties can be obtained, at least in shot sizes 20 mm. and larger. However, as previously mentioned, these items are purchased on a performance basis, and the selection of the type of steel used is the responsibility of the manufacturer (primary contractor).

As an indication of the Ordnance Department's use of low alloy steels, and after excluding ballistic steels, two-thirds of its alloy steel requirements were specified in composition comparable to NE grades during August 1943. Again with the exception of ballistic steels, 42% of Ordnance alloy steel requirements for August were of the three alloy type. In view of the alloy steel scrap situation, the steel industry and the War Production Board are attempting to convert as much alloy tonnage as possible to these triple alloy steels.

*EDITOR'S NOTE: Discussion from the floor indicated that quench-cracking was the worst fault of the 9400 steels, especially when silicon was on the high side of the specification, but another commentator observed that much trouble of this sort is avoided if the parts are heated so no surface carbon is lost.

NE Steels in Airframes and Engines

By J. B. Johnson
Chief, Materials Laboratory
Engineering Division, Army Air Forces

THE AVIATION INDUSTRY has become one of the larger users of alloy steel (approximately 17%), and of this total tonnage, one-fifth is National Emergency steel. The NE steels which are used are those selected by the Technical Advisory Committee on Aeronautical Steels appointed by the Conservation Division of the War Production Board in 1941. Three series of NE steels then in existence — 8600, 8700 and 9300 — were selected. Of these three 8600 represents approximately 63% of the total NE steels used in aviation last month; the 8700 series approximately 36%, while the 9300 series is used only to a very limited extent. The 9400 series, which was not selected by the Committee, has been used for tools and minor applications; its total tonnage is less than 1% of the total NE steels used in the aircraft industry.

The airframe branch of the industry has endorsed the NE steels to a much greater degree than the engine and accessory manufacturers. This was not due to any lack of cooperation or desire on the part of the latter, but to the nature of the tests required before a change in material is permitted by the purchasers — the Armed Services. Engine parts are required to pass a 150-hr. model test, but often designers extend this to from 200 to 1000 hr. in order to get a better idea of the endurance characteristics of the part fabricated from the new material.

Ordinary laboratory tests such as tensile, impact and shear are satisfactory for determining the design characteristics of steels to be used for airframe construction. Another important characteristic is the weldability, and weldability of the 8600 and 8700 series was determined by tests made in several laboratories and in production plants.* The consensus was that they could be welded with about the same facility and with the same technique as *(Continued on page 124)*

*EDITOR'S NOTE: See, for example, articles by Morse Hill and H. C. Willis in *Metal Progress*, September 1942 and April 1943.

Although this paper was not a part of the ⚙ Group Discussion of National Emergency steels at the Chicago Convention, its content is quite apropos and it can therefore properly be regarded as a supplement to Mr. Johnson's general statement on the use of NE steels in aircraft

Steel Aircraft Tubing of NE8630 Steel

ARTICLES IMMEDIATELY PRECEDING this one outline the changes in normal supplies of ferro-alloys and steel scrap that led to the formulation of the NE steels. Mr. Johnson has also indicated that certain of these triple alloy steels are already widely used in the manufacture of airframes. It will be my task, therefore, to describe the properties of one of the new alloys in the form of thin walled seamless tubing.

The aircraft industry has been a large user of the 4100 series steels — especially 4130, nominally 0.50% manganese, 1.00% chromium and 0.20% molybdenum. The group of technical men studying the conservation of alloys recommended that the chromium in these steels be reduced by half, and manganese increased by half, relying on "tramp" nickel in the scrap to bring the hardenability of the new compositions in line with the old 4100's.

Specifically NE8630 was developed on this basis to substitute for A4130 and X4130.

After the indications showed that NE8630 would be a fair substitute for 4130, the data were presented to the aircraft industry. Before adopting such a change or any new steel, it is of course necessary to do a great deal of model testing, and conduct other tests such as for weldability, hardenability, and mechanical tests on parts fabricated from this new steel. Many investigations on NE8630 were conducted by the Army Air Forces Matériel Center, by many aircraft companies, steel companies, and tubing mills, and summarized in Air Corps Technical Report No. 4799 (reprinted largely in *Metal Progress* in September 1942 and April 1943).

The question of substitution for bar stock and forgings was not a very difficult decision to make; however, where the finished products are used in light gages such as for tubing and sheet, which are used in the aircraft industry, the questions of mechanical testing, weldability, hardenability, and the meeting of specification requirements are of utmost importance.

As part of this general program, the Summerill Tubing Co. investigated the behavior of NE8630 in the form of tubing as supplied for aircraft use. A great deal of attention was paid to the comparison between NE8630 and 4130, with which it has had a great many years of experience. The main basis of this paper will, therefore, be concerned with these findings.

If one will refer to Grossmann's charts showing how the hardenability is influenced by the various alloying elements (data sheet on page 742 of *Metal Progress* for October 1943) one can readily see that manganese and molybdenum are by far the most effective alloying elements in increasing hardenability; then follows chromium — nearly as effective — and silicon and nickel in that order with rather weak influence. It is

By A. J. Williamson
Chief Metallurgist, Summerill Tubing Co.
Bridgeport, Pa.

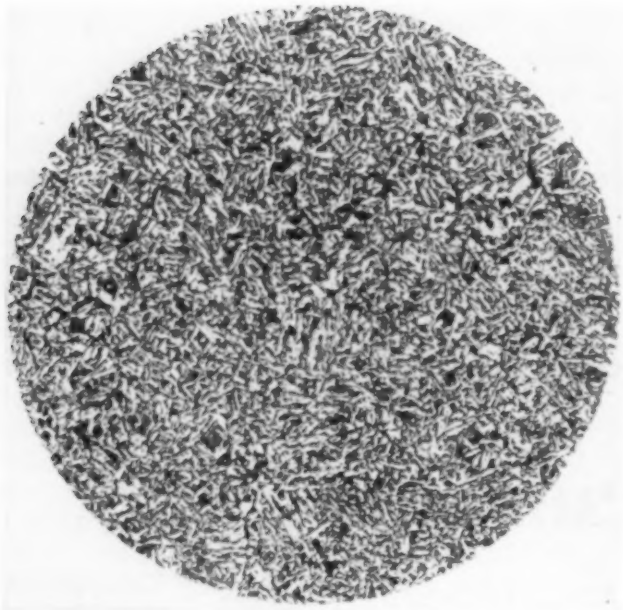


Fig. 1 — Well Defined Acicular Structure in NE 8630 Tube (¾-In. O.D. by 0.065-In. Wall), Normalized From 1700° F. Magnified 200 diameters

	Normalized	Normalized and Drawn at 900° F.
Ultimate strength	113,000 psi.	107,000 psi.
Yield strength	75,000 psi.	85,000 psi.
Elongation in 2 in.	21%	22%

obvious that if the chromium content is reduced from 1% to 0.5% there is quite a decrease in hardenability, all other elements being the same. There is present in 4130 steel some residual nickel, sometimes running as high as 0.40%, but normally from 0.10 to 0.25% under present conditions, and this steel would have a higher hardenability than an 8630 steel based on the chromium and nickel contents as reflected by Grossmann's curves. Of course, an increase in manganese in NE8630 replaces some of the hardenability lost by a large reduction in chromium.

Based on these curves, it is apparent that the increasing amounts of uncontrolled residual or tramp nickel in 4130 will have a greater effect on its hardenability and weldability than designedly raising the nickel content to the 0.40 to 0.70% range and dropping the chromium to 0.50% in NE8630. For some reason or other, the percentages of chromium and nickel appear to have a greater effect on weldability than does the manganese content; on the basis that weldability and hardenability are closely related we have a substantiation of decreased hardenability of NE8630 as compared with 4130. In light sections, such as tubing, this decreased hardenability is not so evident; in other words, the effect of mass is again important.

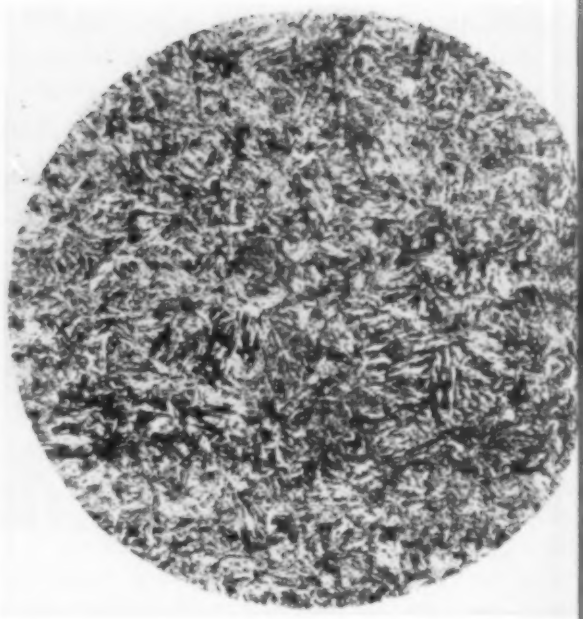


Fig. 2 — Sample of Fig. 1 Was Then Oil-Quenched From 1650° F., Tempered at 800° F.

One other important consideration affects chromium contents of 0.75% or more. Heat treaters know that there is quite a difference in the hardening of chromium steels depending upon the temperature at which they are heated for hardening. In other words, the effect of undissolved carbides — or rather the lack of expected hardenability if carbides are undissolved, as in a short heating above the critical — will show unmistakably in a 1% chromium steel such as 4130. It will show a greater lag in carbide diffusion at the heat treating temperature as compared to the NE steel containing 0.50% chromium. It can be expected, therefore, that the NE8630 steel may require less soaking time than 4130, at the various hardening and normalizing temperatures, to effect the greatest hardenability. This factor may help in the heat treatment of 8630 and may be a decided advantage over 4130.

There has been a lot of welding done on 8630, and some fundamental tests on its weldability have been carried out in one of our research institutions, all of which indicate that 8630 is less susceptible to weld cracking than is 4130. As a matter of fact, the 8600 steels are more weldable than the 4100, even when the 8600's have a considerably increased carbon content. It may be that further research will indicate that a higher carbon content can be used in the 8600 series, thus enabling the constructor to use much higher strength steel with equal or better weldability than with present 4130.

Tests on Tubing

The Summerill Tubing Co. obtained an open-earth heat of NE8630 which conformed to the following analysis:

	0.30%	Cr	0.50	P	0.016
n	0.77	Mo	0.19%	Grain size 6 to 8	
	0.51	S	0.018		

One can observe that this hits the average of e chemical specification and the results obtained herefrom should be considered as average.

The tubing was reduced in the mill in a succession of dies and process anneals similarly to 4130. From all observations, the material cold worked satisfactorily. One particular factor in the processing of NE8630 as compared to 4130 was in the pickling solution; the new steel is much more rapidly attacked in a 14% sulphuric acid solution, and must be watched carefully. This may be caused by the decrease in chromium content and/or the addition of nickel.

The NE8630 tubing was subjected to various mechanical tests, including flattening and flaring, and in every case the results compared favorably with 4130. This was true for all the wall thicknesses from 0.187 to 0.015 in.

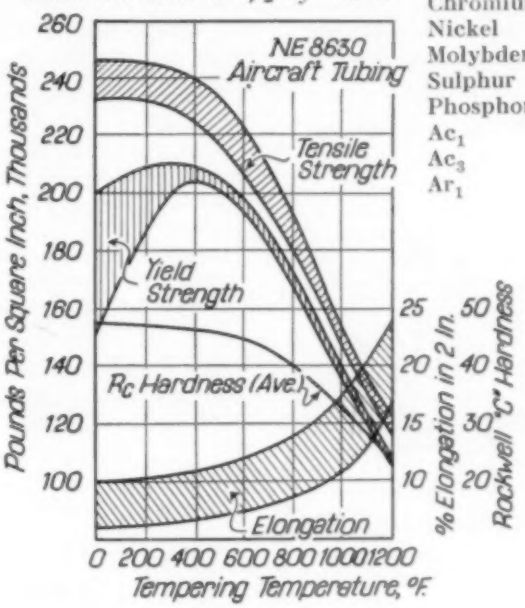
The tubing was normalized, also quenched and tempered; from all observations the normalized properties were similar to those for 4130. With this particular heat they even appeared to be superior. There was noted an appreciable improvement in the yield strength by a low tempering treatment after normalizing. Figure 1 shows the normalized condition for a 0.120-in. wall tube. The appearance is similar to that of 4130, excepting that it appears to be a better defined acicular structure. Figure 2 is a photomicrograph of a quenched and tempered tube.

Quenched and tempered properties are shown in Fig. 3, which covers the range of mechanical properties exhibited by the various wall thicknesses, ranging from 0.120 to 0.035-in. In general, the properties are as good as 4130. Experience thus far has shown that there appears to be a little more uniformity in heat treated properties of NE8630 as compared to 4130. It has also been possible to lower the quenching temperature by 50° F., thus facilitating heat treating procedures and avoiding the associated possibility of decarburization.

Welding of tube samples showed that the material welds satisfactorily, and Fig. 4 shows hardness readings across the joint after arc welding on two tube sizes. Different tube sizes, which were typical aircraft butt welds, had very little change in ultimate strength, as shown in the caption of Fig. 4.

McQuaid-Ehn grain size was determined on the tubing as received (2 in. o.d. by 0.187-in. wall), and on 1 in.

Fig. 3 — Mechanical Properties of Heat Treated NE 8630 Tubing. Size ranges from 1⅛ in. o.d. by 0.120 in. wall to ½ by 0.035



	Specification	Actual
Carbon	0.28 to 0.33%	0.30%
Manganese	0.70 to 0.90	0.77
Silicon	0.20 to 0.35	....
Chromium	0.40 to 0.60	0.50
Nickel	0.40 to 0.70	0.51
Molybdenum	0.15 to 0.25	0.19
Sulphur	0.040 max.	0.018
Phosphorus	0.040 max.	0.016
Ac_1		1335° F.
Ac_3		1470° F.
Ar_1		1220° F.

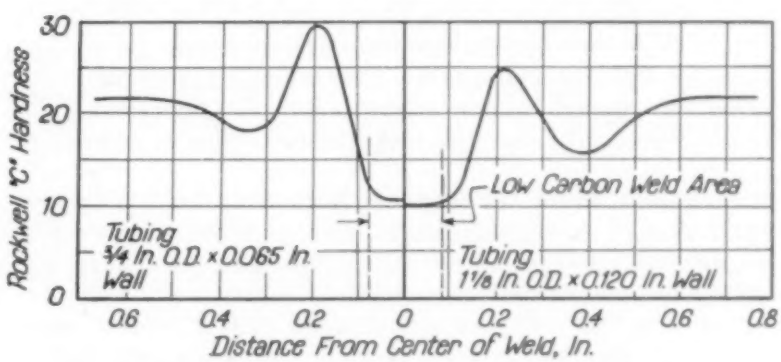


Fig. 4 — Hardness Surveys Across Two Butt Welds. Tensile tests on three joints given below

	1⅛ by 0.120	¾ by 0.065	½ by 0.035
Before welding			
Ultimate	118,000 psi.	125,000 psi.	116,000 psi.
Yield	102,000	116,000	108,000
After welding			
Ultimate	105,000	120,000	111,000
Yield	103,000	108,000	109,500

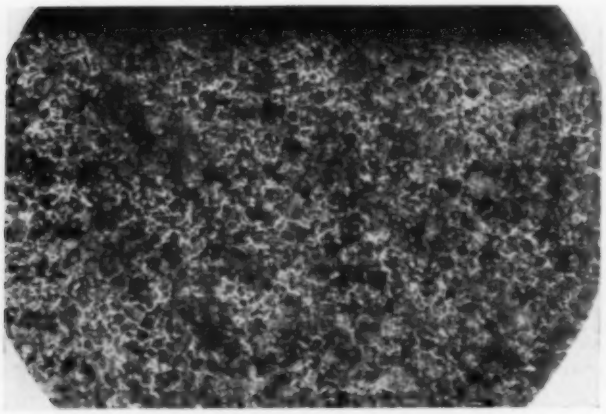


Fig. 5 — McQuaid-Ehn Grain Size Test on 2-In. Tube as Received. Sample was carburized during this standard test. Grain size No. 8; 100 diameters

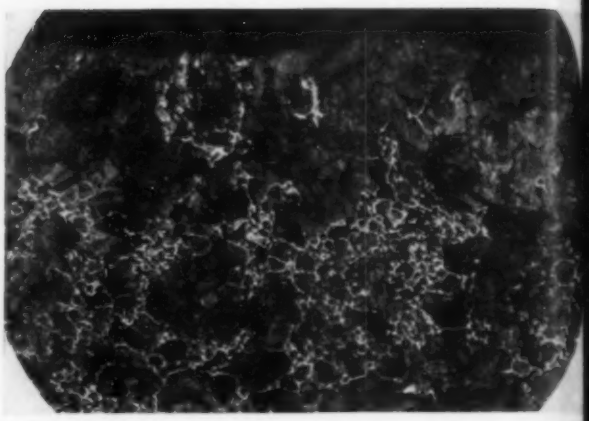


Fig. 6 — Tube Cold Worked From 2-In. by 0.187 t 1-In. by 0.095 Shows Duplexed No. 3 and 8 Grain

by 0.095, and it is interesting to know that whereas the tubing was fine grained as received, the grain size on the 1 in. by 0.095 tube showed some duplexing. These different grain sizes are shown in Fig. 5 and 6.

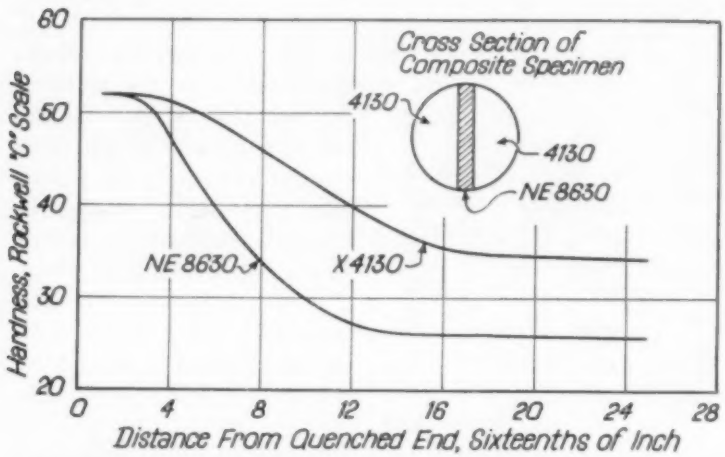


Fig. 7 — Jominy End-Quench Hardenability Curves (Average) for NE 8630 and X 4130. Normalizing temperature: 1700° F. Quenching temperature: 1700° F. Grain size: 6 to 8. Thin strip made into composite 1-in. round as shown

Figure 7 shows the hardenability curves for this heat of NE8630 steel as compared to an average 4130. It should be pointed out that the hardenability experiment for 8630 was with a narrow strip (0.187 in. thick) whereas the 4130 was with a 1-in. bar. The strip was made part of a 1-in. round section, as sketched in Fig. 7, and the assembly subjected to the regular Jominy end-quench test. We believe that these hardenability curves are typical. It will be noted that, at a distance of $\frac{3}{16}$ in. from the end, the NE8630 and 4130 are somewhat similar, whereas in most of the length there is a 10-point divergence of hardness. Thus, for light wall tubing and sheet there should be no trouble in normalizing and heat treating; some adjustments would need to be made for more massive parts.

There has been found some difference in th relation between Rockwell hardness and tensil strength with NE8630 as compared to 4130. Thi slight difference is shown in Fig. 8.

Because of the favorable reports on weldin and heat treatment, from the field, it i expected that NE8630 will replace 413 in more and more applications of air craft tubing, even in the post-war period Certainly, the favorable results in manu facturing, the better balance of alloying elements, and the better weldability con firm this belief.

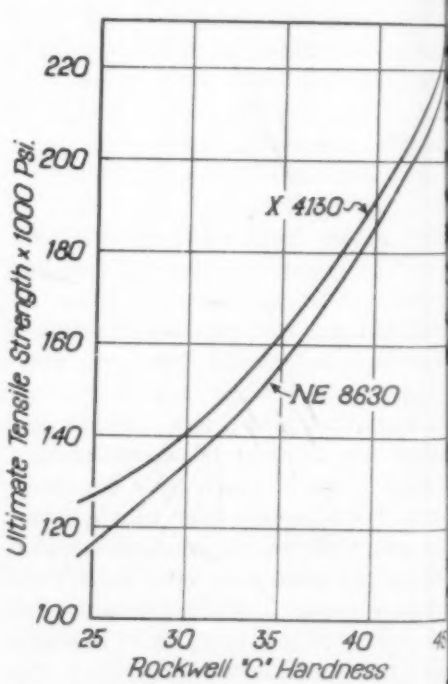
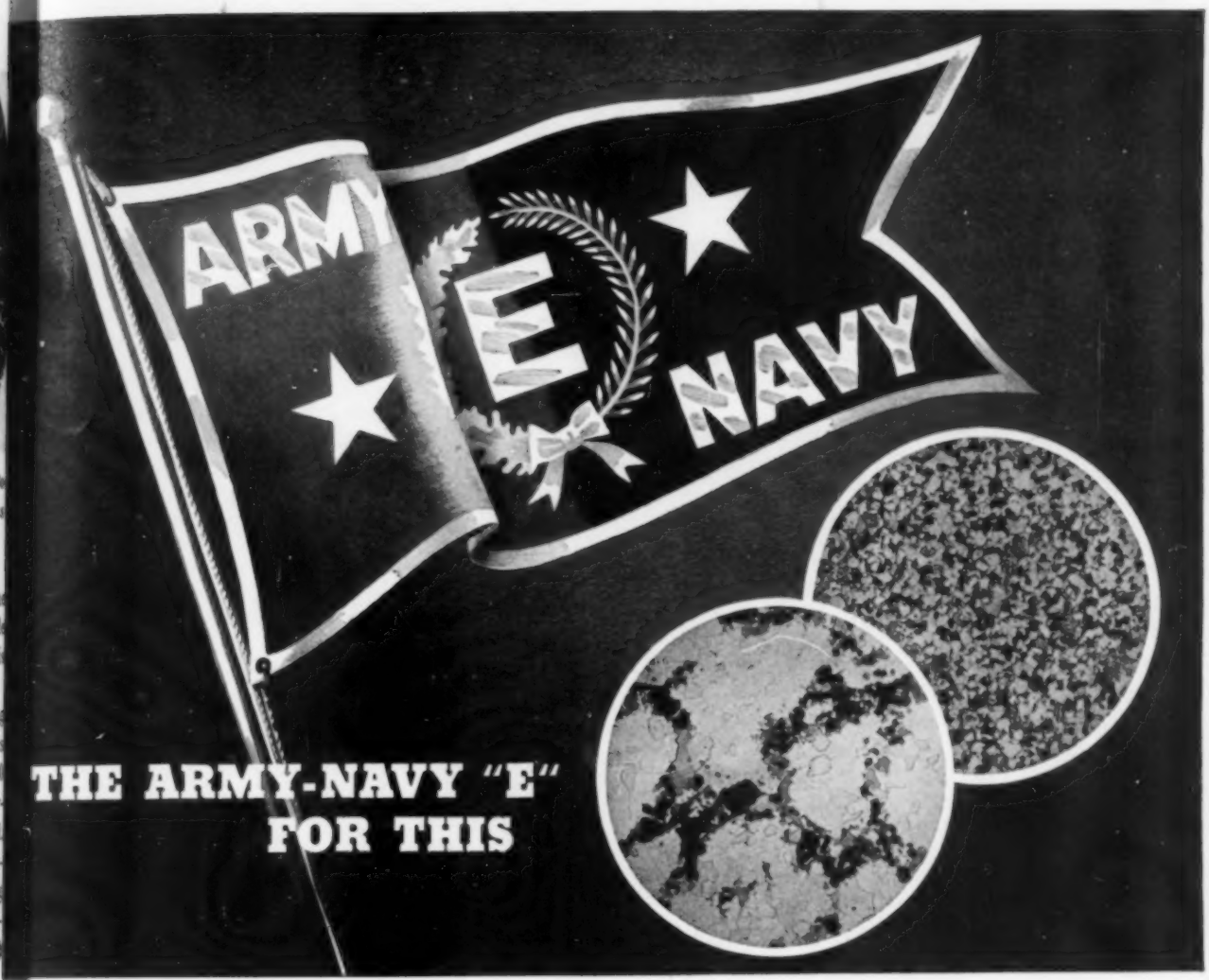


Fig. 8 — Correlation of Hardness an Tensile Strength for NE 8630 an X 4130 Thin Wall Tubing for Aircra



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Personals

A. C. WEIGEL, vice-president, Combustion Engineering Co., has been elected second vice-president of the American Welding Society. Elected to district vice-presidents are F. C. FYKE, head, materials division, general engineering department, Standard Oil Development Co., New York and New England; C. H. JENNINGS, section engineer, Westinghouse Electric & Mfg. Co., middle eastern district; G. N. SIEGER, president and general manager, S-M-S Corp., middle western district; E. C. CHAPMAN, metallurgist in charge of welding research, Hedges-Walsh-Weidner Div., Combustion Engineering Co., southern district; and J. C. GOWING, southern California representative, Hobart Brothers, Pacific Coast district.

CHARLES R. INCE, ass... sales manager, St. Joseph Lea... has returned to his company ... spending the past 16 months ... special consultant in the War ... duction Board in Washington.

Named as ... Edward de ... Campbell Memorial Lecture... 1944: G. R. FITTERER, he... the department of metallurgic... gineering at the Universit... Pittsburgh.

CARL H. SAMANS has resi... as copper consultant, Conserv... Division, War Production B... and returned to his former po... as research metallurgist, Amer... Optical Co., Southbridge, Mass.

HOWARD J. SCHMITT, form... a student in metallurgical engi... ing at the University of N... Dame, is now employed by ... Aluminum Co. of America at ... New Kensington plant.

BERNARD RUBIN has been g... uated from Pennsylvania State ... lege and is now employed in ... metallurgical laboratory of ... Corning Glass Works, Corn... N. Y.

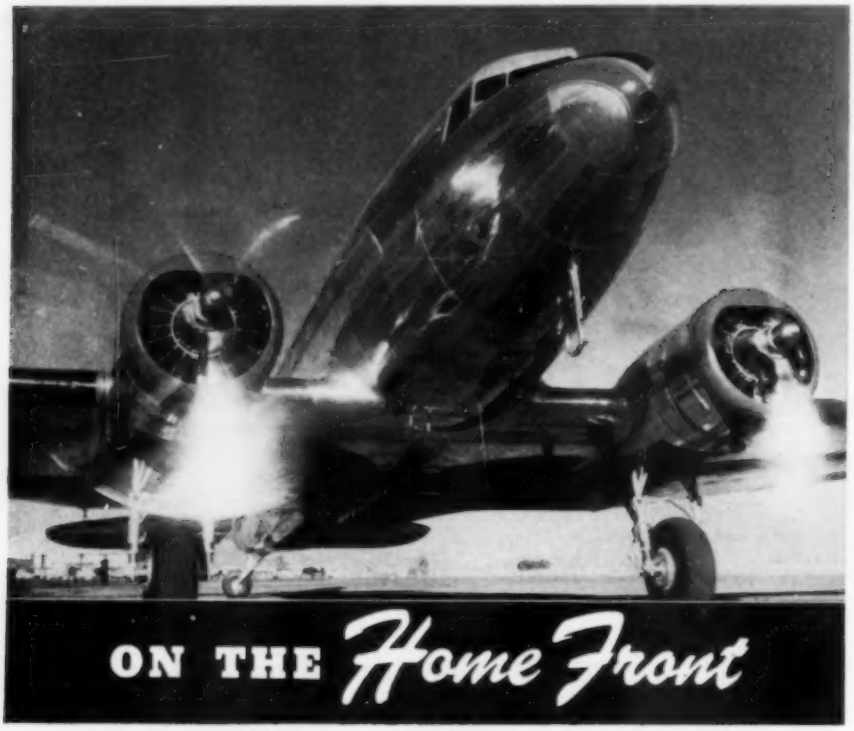
AUSTIN HILLER, formerly ... the Parker Gun Works of Rem... ton Arms Co., Ilion, N. Y., is ... metallurgical engineer for Tanta... Defense Corp., North Chicago.

RICHARD S. COLE, form... with Remington Arms Co. at I... ver, is now employed as electro... allurgist for the U.S. Bureau ... Mines in Norris, Tenn.

Transferred: EDGAR W. Ra... , from the Pittsburg, Calif., p... of Columbia Steel Co. to the ... Francisco office as contact m... lurgist and assistant to the ... metallurgist.

MERTON C. PARKER has ... transferred to the Seattle Dis... Office of the U.S. Army Engin... and assigned duties in enginee... design, specifications, and mat... inspections.

PAUL E. FLOYD has beer... leased from his post in the ... and Steel Branch of the War ... duction Board to resume his for... position as district manager in ... Chicago branch office of the ... gheny Ludlum Steel Corp.



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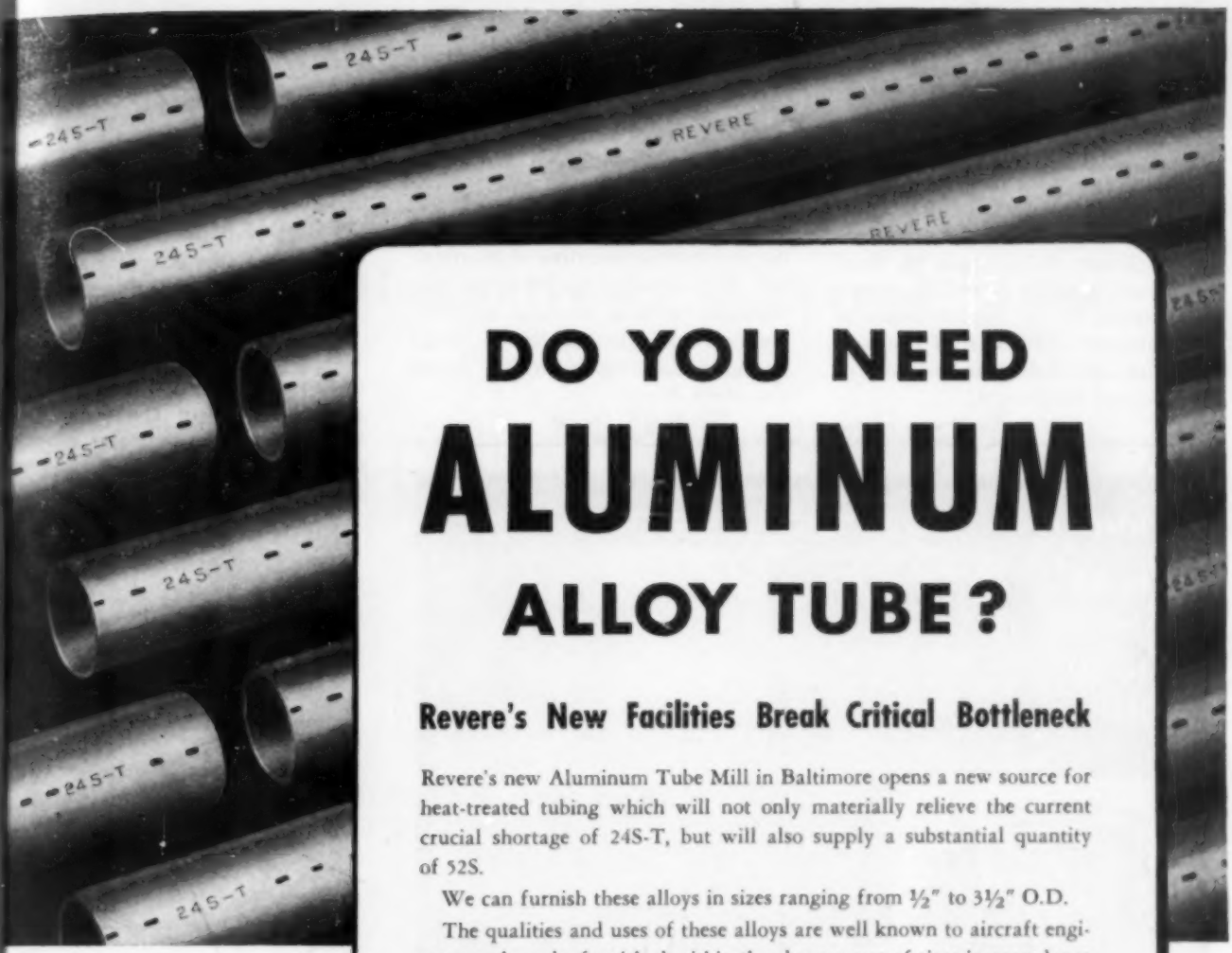

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Mr. Louis J. Galbreath, District Manager
Revere Copper and Brass Incorporated
Magnesium-Aluminum Division
230 Park Avenue
New York 17, New York

Mr. Richard K. Snively, District Manager
Revere Copper and Brass Incorporated
Magnesium-Aluminum Division
1301 Wicomico Street
P. O. Box 2075
Baltimore 3, Maryland

Personals

Awarded the Alfred Noble Prize presented by a group of engineering societies: B. J. LAZAN, chief engineer, Sonntag Scientific Corp., Greenwich, Conn., for his paper in the February 1943 issue of *Transactions* of the American Society of Mechanical Engineers.

JOSEPH H. JONES, formerly with the metallurgical department of Republic Steel Corp., Alloy Division, Massillon, Ohio, is now superintendent in charge of Republic Steel's new Gun Bloom Works at Canton, Ohio.

R. J. A. FRICKER, chairman of the publicity committee of the British Columbia Chapter, has resigned as heat treating superintendent, Dominion Bridge Co., to go on active service with the Royal Canadian Navy.

Promoted: DONALD S. KLIPP, from Cleveland district manag to assistant general manager of sal of the Timken Steel and Tube Div sion.

GEORGE L. CRAIG, formerl metallurgist and research enginee has been appointed director of r search of Calumet and Hecla Co solidated Copper Co.

M. M. CLARK, formerly ma ager of the bar and semi-finishe materials bureau in the metallu gical division of Carnegie-Illino Steel Corp., is now sales engine for Metal Parts and Equipment C Chicago.

HAMLIN A. CALDWELL, fo merly assistant chief metallurgi of the Tennessee Coal, Iron an Railroad Co., has been named chi metallurgist.

Transferred from Wright Fiel to the Eastern Procurement Di trict, Army Air Forces, New Yor City: MORSE HILL, member of th Executive Committee, Dayton Cha ter.

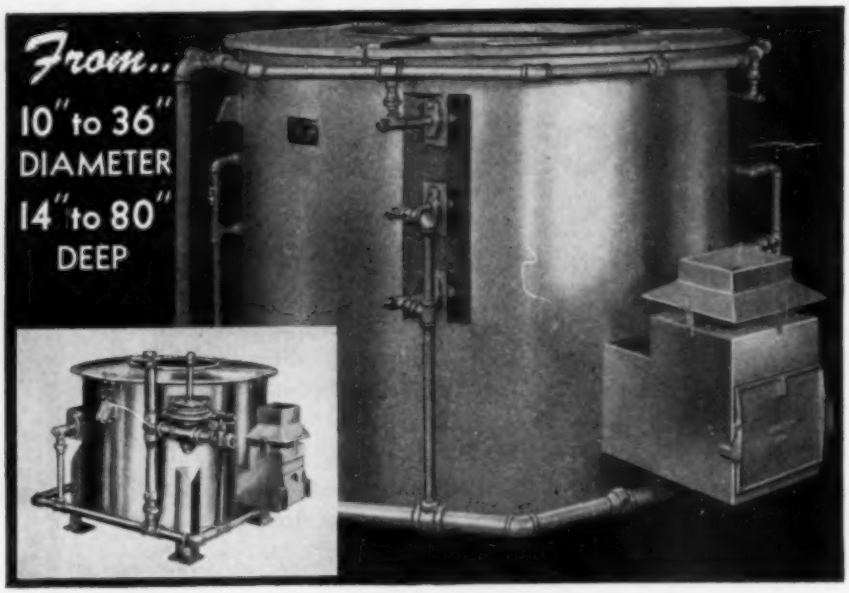
RICHARD F. MILLER, formerl of the U.S. Steel Corp. Researc Laboratory, Kearny, N. J., has bee appointed development engineer i the Stainless and Alloy Steels Div sion of Carnegie-Illinois Steel Corp Pittsburgh.

Transferred by General Electri Co.: DANIEL A. GIFFIN, test eng neer, from the industrial contro department at Schenectady to th turbine department at Lynn, Mas

Promoted: EDMUND F. BURK, from lieutenant (j.g.) to lieu tenant U.S. Coast Guard Reserv and transferred from Washingto D. C., to New York, on duty involv ing design and construction c combat vessels.

F. L. MEACHAM, formerl manager of the war productio engineering division of Frigidair Division of General Motors Corp has been appointed manager o sales and service for the Chica Vitreous Enamel Product Co Cicero, Ill.

E. MILES SWARTS II is no employed by the Aluminum Co. o America as a junior metallurgist i the Massena, N. Y. plant.



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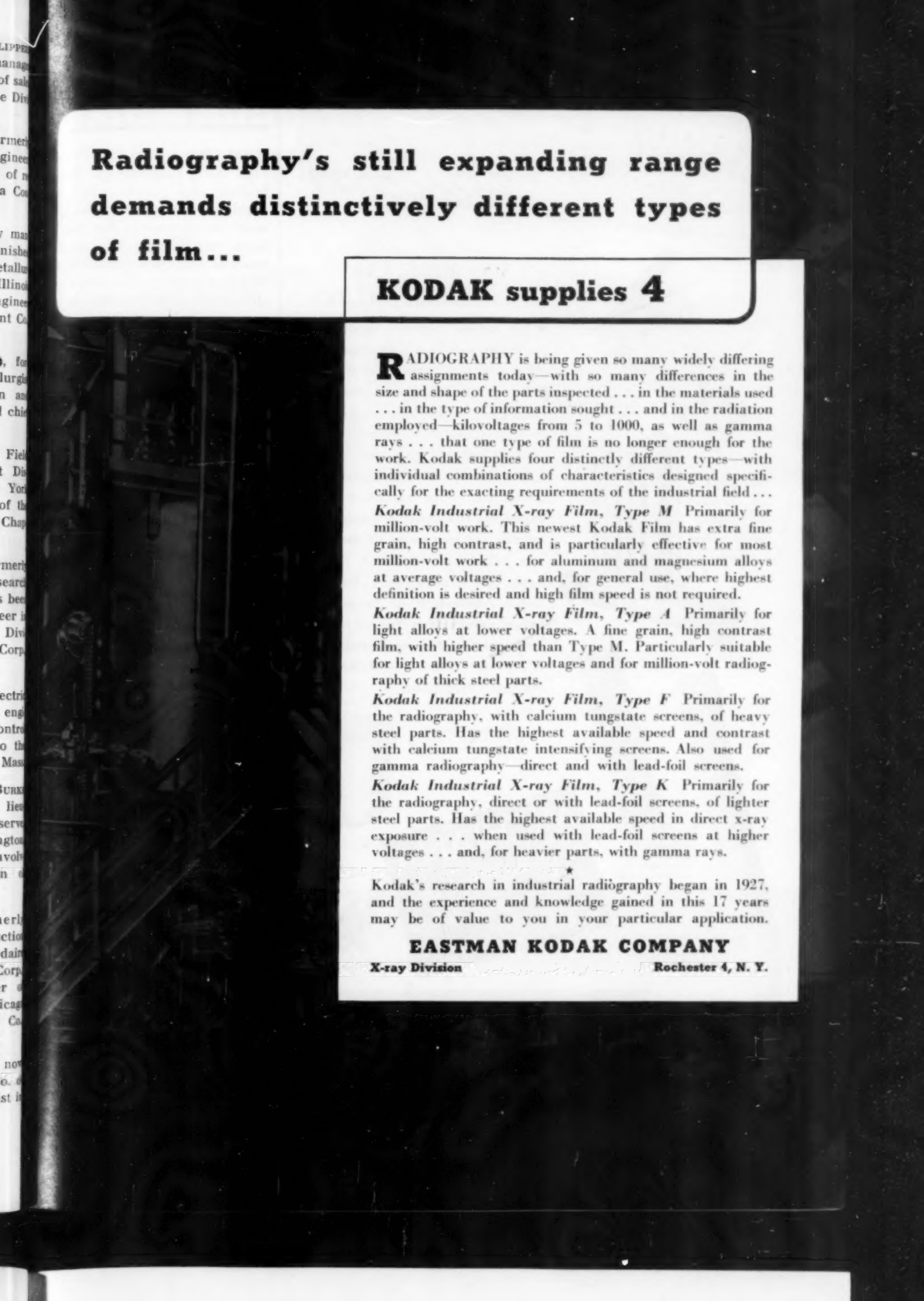

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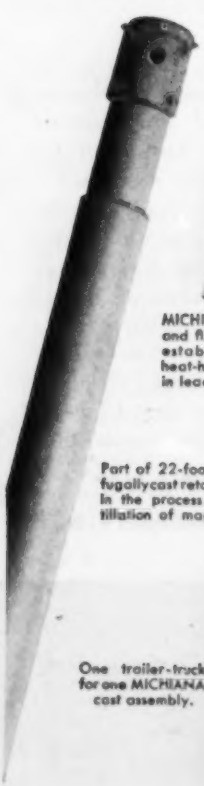

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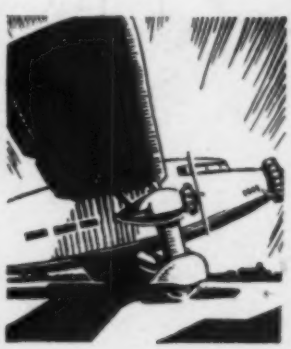
Airplane Steels

(Cont. from p. 114) the 4130 and 4140 steels, respectively. If preheating and post-heating were required for the 4100 steels, they were also necessary for the NE steels mentioned. The original analysis contained 0.40 to 0.60% nickel, and when the nickel was changed to 0.40 to 0.70% it was necessary to repeat the weldability tests. Tests made at the airframe plants indicated that the nickel did not have sufficient effect on the weldability to cause cracking. However, the more sensitive tests made at Battelle Memorial Institute for the Army Air Forces indicated that the NE8630 series with the maximum of 0.70% nickel becomes a borderline steel, and the crack sensitivity may be affected by the microstructure.

The engine manufacturers have completely model-tested a large number of miscellaneous parts for engines — principally the smaller parts such as nuts, studs, bolts, adapters for tubing and shaft bearings, brackets, tube connections, clamps, dowels, flanges, levers, and plugs. Some of the larger parts are the forged steel crankcases and cylinders. NE steels have not been adopted for crankshafts, connecting rods, production gears and main auxiliary drive shafts. These parts are generally manufactured of 4300 or a high alloy carburized steel for which the NE steels are not suitable alternates.



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MALLORY *Standardized Resistance Welding Electrodes*

Post-War Metals

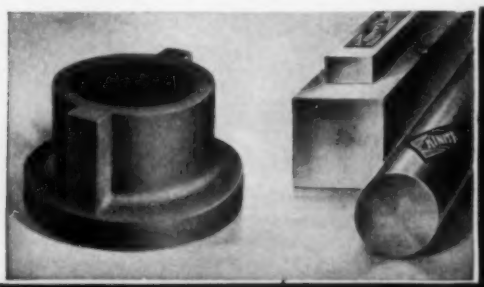
(Continued from page 77)

be placed on many of the alloys by chemical means. Other surface finishes have been devised to withstand corrosion and discoloration when exposed to industrial atmospheres — and this has vastly improved their utility in exterior architectural trim. The electrical and heat conductivity of aluminum is third only to copper and silver.

Mechanical and physical properties of aluminum alloys — both inherent and enhanced by science — are so interesting that aluminum will certainly be used in a thousand unusual ways, and is sure to be exploited vigorously by producers with extensive plants to keep busy. Much of the competition with other materials of construction will come in items where light weight is desirable. Everything that moves and stops and starts, when inertia must be taken into account, must consider aluminum and its alloys, cast, extruded, rolled, forged, spun or machined. Its corrosion resistance and non-toxic effect, as well as easy fabrication, will adapt it to all sorts of food containers, cookers, and utensils. Lightness, beauty, corrosion resistance and weldability adapt it to many consumer's items from furniture to ashtrays and foil wrappers. Electrical conductivity and ductility bring it into wiring and motors. Heat conductivity and castability adapt it to cylinder heads for gas engines. The Aluminum Co. has coined a new word "Imagineering" to denote what should be done in appraising post-war products made of this metal.

Unfortunately, the American sources of high grade ore are limited; after the war we will return to the rich and large deposits across the Caribbean in South America. (Meanwhile we are developing more costly refining operations on lower grade ores existing here in enormous quantity.)

Magnesium is such a baby among the metals that its ultimate advantages (and limitations) can be little more than guessed. War demand for incendiaries and aircraft fittings (castings and forgings) has expanded the production capacity 100-fold. The sources are natural brines, sea water, and a variety of limestone called dolomite — all available in truly infinite quantity. Several different reduction processes are being used in the Government-owned plants; some will undoubtedly be abandoned as too costly, but the information gained by their operation will help bring the price of the metal down to compete with aluminum. Magnesium is considerably lighter than aluminum, and therefore was competitive, even before the war, in portable hand tools and utensils. It is also available in many alloys harder and stronger than the pure metal, and having special properties for specific uses. It has certain disadvantages, though. It tarnishes easily, and is subject to "stress corrosion" difficult to control. By its atomic structure it is inherently more brittle and difficult to work than aluminum. It has a high chemical affinity for oxygen, but recently safe methods for welding the metal have been discovered. It is safe to say that many of the things that now seem to be drawbacks to the utility of this interesting metal will be removed by the intent research that is sure to be expended.



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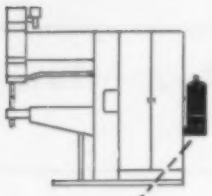

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a d-c current interruptor — *without arc*

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- NO ROUTINE MAINTENANCE REQUIRED
- ACCURATE CONTROL OF SECONDARY CIRCUIT DUE TO ABSENCE OF ARCING IN PRIMARY
- INCREASED EFFICIENCY OF ELECTRO-MAGNETIC ENERGY SYSTEM — SHORTER CHARGING TIME
- SPEED INCREASED 20% OVER MACHINES OPERATING ON CONTACTOR SYSTEM

THE SCIAKY DYNATROL provides the answer to contactor problems on electro-magnetic stored energy resistance welding equipment. This high-speed device performs the function of accurately interrupting the charging current to the reactor *without arc*.

The problem of interrupting a d.c. current in a highly reactive circuit has always been considered difficult because it is necessary to dissipate the electro-magnetic energy stored in the circuit in order to stop the flow of current. On former Sciaky machines, this was accomplished by a contactor unit, which together with an arc-blowing device, arc-laminating shields, etc., produced a highly accurate interruption of the charging current.

However, in industrial production, the continuous arcing finally results in a deterioration of the contact tips, requiring periodical maintenance and replacement. It was considered desirable to solve this problem in such a way that the same consistent welds be produced without any maintenance of the interrupting device. To this end, the DYNATROL was developed and was found to be not only a means of more accurate and efficient current interruption, but also, because of the shorter charging time, *actually increases operating speeds 20%*.

The DYNATROL is available on all Sciaky Stored Energy machines up to 50KW.

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Airplane Wings of Magnesium*

By V. H. Pavlecka and John K. Northrop

MANY MODERN AIRPLANES are almost solely dependent upon monocoque or semi-monocoque construction — wherein a substantial proportion of the load is carried in the skin — for their rugged structural integrity. The best materials for pure monocoque construction are those having low specific gravity and relatively high modulus of elasticity, for high compressive strength before buckling occurs. On this basis certain plywood combinations would prove best; unfortunately these are not yet available in quantity, nor sufficiently uniform in properties.

Stressed skin structures of steel have been commonplace in other fields of endeavor, but when designed to weight limits acceptable for modern aircraft, the result is a thin sheet operating within its buckling range, "stiffened" by a costly multitude of small beams spot welded or riveted to the main cover sheet.

Aluminum alloys have therefore been used for most external aircraft coverings. Flat aluminum sheet, however, has a higher density than desirable, and is rarely used without some internal stiffening. Likewise, the comparatively thin cover sheets buckle within the range of normal flight loads, as can readily be seen during a short ride in a modern transport. Spot welding has not as yet been able to supplant riveting, and so most modern aircraft contain from 100,000 to over 1,000,000 rivets, each requiring a layout, one or two holes, and two operators to drive.

Great advances in the science of aerodynamics have proven that the effects of rivet heads (even if countersunk), local buckling, and general surface irregularities are much more detrimental than previously believed, and that the aerodynamic form of the external surface must be smooth, uniformly finished, and without local buckles if minimum drag is achieved.

Provided an economical joining method could be found, strong magnesium alloys appeared to be the most attractive alternative to aluminum. Less than two-thirds the weight of aluminum, and not much over one-fifth as heavy as steel, such materials have a relative stiffness, for a given weight, of 2.5 times that of aluminum and 19.5 times that of steel.

First, however, a method of welding had to be found, superior to the conventional methods requiring copious use of flux. Successful fluxes are all extremely corrosive if the slightest contamination remains in the weld. The problem was finally solved by the discovery of the "Heliarc" (described in *Metal Progress*, Sept. 1942, p. 404).

Basically, this method of electric welding consists in striking a direct-current arc between the work and a tungsten electrode, simultaneously feeding helium gas to the weld area through an annular nozzle surrounding the electrode. Additional metal, as needed, is added from an uncoated welding rod of the same magnesium alloy.

(Continued on page 130)

*Abstracted from prize paper in the 1942 Industrial Progress Award Program conducted by the James F. Lincoln Arc Welding Foundation.

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THE SEARCH THAT NEVER ENDS

IN THE industrial life of America, research has been of constantly increasing importance. And today it is a national resource, for the research of industrial and college laboratories is proving its value in War.

To the Bell System, research is an old idea, for the telephone itself was born in a laboratory. Behind its invention, sixty-nine years ago, were researches in electricity and acoustics and in speech and hearing.

And, ever since, there has been a laboratory where scientists have searched to know more about these subjects; and with their associated engineers have applied the new knowledge, fitting it with all the old, to make the telephone better and better.

Their fields of inquiry have broadened and deepened through these years; they inquire into all the sciences and engineering arts which have any promise of improving the telephone. Much has been learned but still more will be, because their search goes on. That is why the telephone laboratory grew to be Bell Telephone Laboratories, Incorporated, the largest industrial laboratory in the world. And it exists to improve telephone service.

Improvements in industry can be left to chance in the hope that some one, sometime, will think of something useful; that some good invention will turn up.

The other way to make improvements is to organize so that new knowledge shall always be coming from researches in the fundamental sciences and engineering arts on which the business is based. From that steady stream will arise inventions and new methods, new materials and improved products.

This is the way of Bell Laboratories. Its search will never end. And as fast as it can the Laboratories will apply its new knowledge practically to the design of equipment and communication systems.

At present—and this started before Pearl Harbor—its trained scientists and engineers and all their skilled associates are concentrating on products of importance to our armed forces. But when this work is happily over they will be ready to continue their developments for the needs of peace.

BELL TELEPHONE SYSTEM

"Research is an effort of the mind to comprehend relationships no one has previously known; and it is practical as well as theoretical." . . . . . BELL TELEPHONE LABORATORIES

Magnesium Wings

(Continued from page 128)

as is being welded. The quality of the weld is high, developing at least 80% of the strength of the parent material. (For design purposes the Army Air Forces allowed 75.9% of the ultimate tensile strength of the metal to be used as the strength of the Heliarc welded seams.

Magnesium alloys can be utilized in aircraft construction in two principal ways: One would be to design for maximum weight reduction, but the rapid strain hardening and corrosion would probably limit weight-saving to approximately 10% over a comparable structure made of aluminum alloy. Since only one-third of the weight empty of a modern military airplane is the airframe, the total weight saving would, at best, amount to some 3.5% of the total empty weight.

This slight gain was judged to be overbalanced by the neces of an extremely careful and exp sive design requiring thin gage sheet. It was therefore decide favor the perfection of the a dynamic shape, and simplicity low cost of structural construct —two qualities more import than small weight savings. Mag sium alloy wings were desig from the test experience and already accumulated, and from calculated loads acting on the w

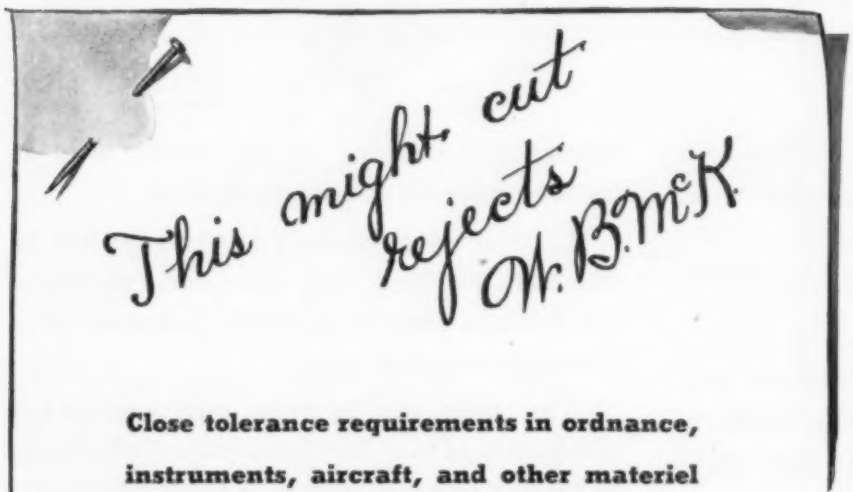
The whole wing structure composed of only two basic ments: The sheet, forming monocoque shell; and an inte skeleton of longitudinals (extru sections) and perforated sheets transverse profile members. number of various extrusions, s as tees and angles, was limited no more than four different tions. Preparation of the pr sections and sheets was also s plified, because flanges and t plates for shaping and riveti were no longer necessary.

Welding shrinkage is fairly e ily controlled as far as dimensi are concerned. Shape distort was more difficult; it manifes itself principally as buckling of monocoque shell, particularly those places where the curvat is not pronounced. However, th was developed a simple and s factory method dealing with buckling distortion, which does harm the metal either internally externally: Heat and pressure applied to the buckled struct through ironing pads, whi relieve the internal strain in sheet. Experiments were carr out to obtain the absolute value internal strains in magnesi alloys induced by welding, and worst, they were on the order 1000 psi. max. (probably due to low modulus of elasticity and yi strength, tending to adjust the m structure readily).

Wing tip and aileron were m of 0.050-in. Dowmetal J-1 anneal alloy. Annealed metal was suita since loads are relatively l Annealed metal is also deliver flatter than the equivalent gage the cold rolled, strain harden sheet. Furthermore, the wing t were formed to shape by drop ha mering of heated sheet at appro mately 600° F., which would h erased most of the cold worki

In the past magnesium allo have suffered from two genera known and popularly misund stood faults. One is the fear

(Continued on page 132)



Close tolerance requirements in ordnance, instruments, aircraft, and other materiel add a function of increasing importance for KSG Silica Gel Dryers. The dehydration of compressed air for surface inspection of interiors and exteriors is a case in point.

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For descriptive bulletins, specific information or engineering assistance, address The C. M. Kemp Mfg. Company, 405 E. Oliver St., Baltimore-2, Md.

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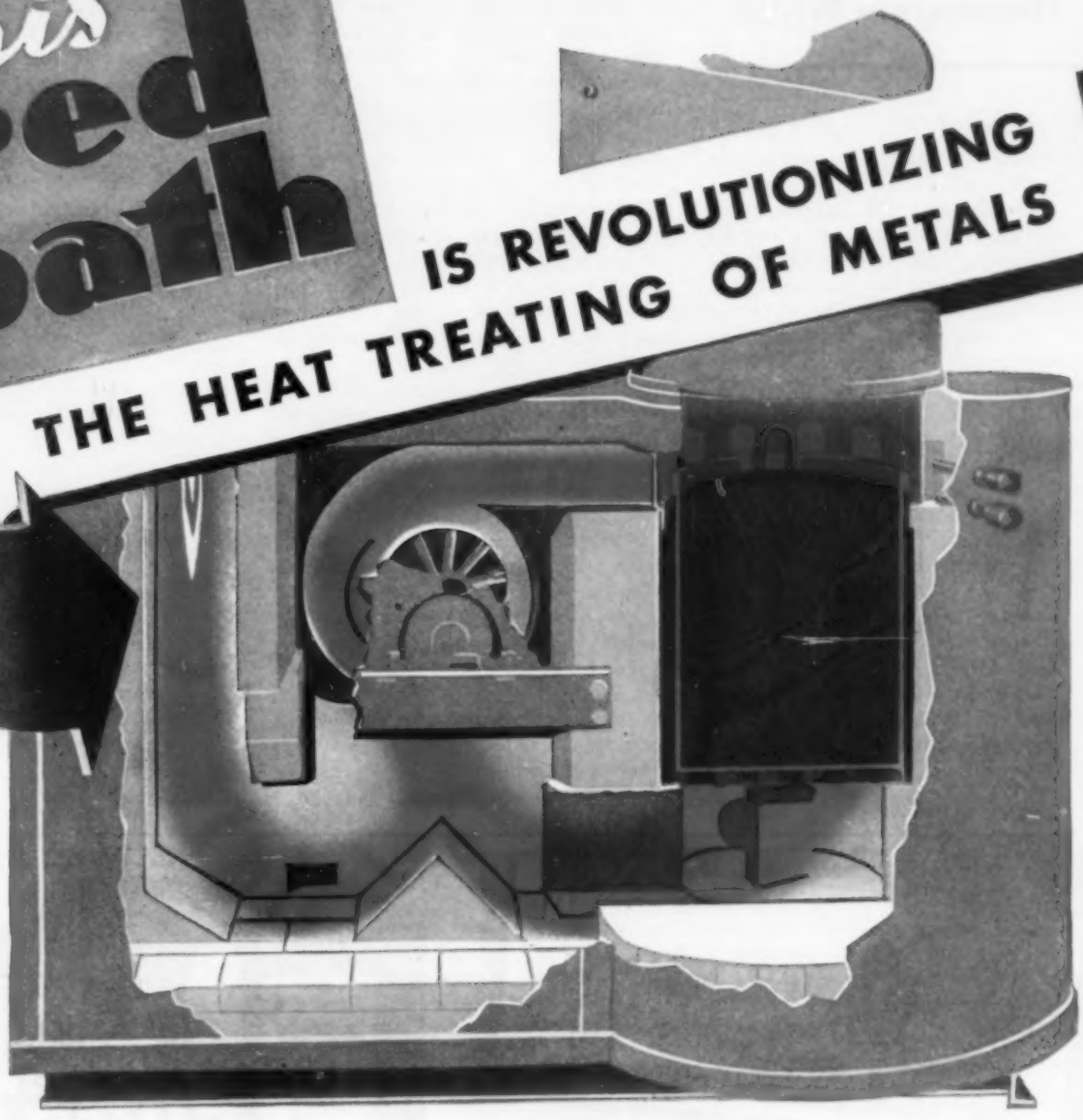

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CYCLONE for accurate, low-cost tempering and nitriding
HYDRYZING for scale-free and decarb-free hardening

Magnesium Wings

(Continued from page 130)

fires, and the other is a conviction that these alloys corrode rapidly.

As to the first, the experience of the authors is that the fire hazard has been greatly exaggerated; the only fires involving magnesium were those started deliberately for test purposes. Zinc chromate primer, generally used by the aircraft industry, acts as a potent extinguisher; it is in fact impossible to ignite painted sheet.

The weather durability of magnesium aircraft structures in service is still undetermined. However, the use of magnesium alloys on several truck bodies through a number of years furnishes convincing proof that corrosion is not dangerous, provided the surface is protected by treating the finished, welded and cleaned structures with sodium dichromate and painting them with standard zinc chromate primer and two coats of finishing lacquer. This covering is sufficiently elastic under load, as well as being abrasion resistant.

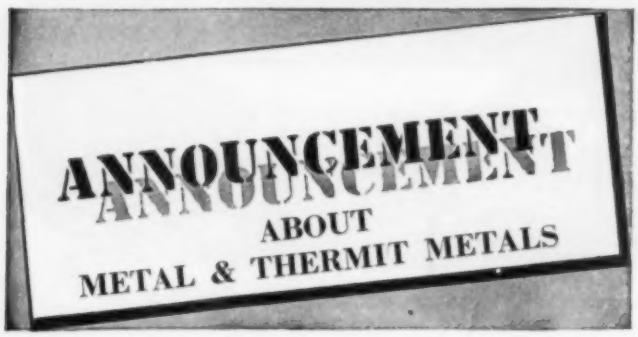
One of the least desirable physical characteristics of the magnesium alloys is their inclination to strain corrosion. The elasticity of the surface finish helps here a great deal, but in addition the authors deliberately avoided stress concentrations in their design and saw to it that the maximum principal stresses anywhere in the wing remain low, viz. 19,170 psi. in tension. Compared to the maximum allowable yield point in tension of 33,000 psi. for cold rolled alloy, this utilization of annealed J-1 material seems wasteful; however, it was done deliberately in order to give rigidity to the outer wing shell, and also to diminish tendencies to strain corrosion.

Tests indicate that the magnesium wings are elastically more flexible in bending, which reduces the peak loads when flying in gusty air. However, they are more rigid in torsion, which cuts down flutter.

Welding costs slightly less per foot than riveting. The great advantage of a welded monocoque is that the actual number of parts is cut in half. Even this is of relatively s moment to the reduction of dr the finished airplane. Within past few years a whole new fa of high performance airfoils been developed in which pr drag has been reduced from 3 50%, but requiring an accur that is virtually impossible obtain in conventional riv structures which develop sur waves within the flight range.

Monocoque welded magne structures have comparatively fl skins which do not buckle loc within the normal range of fl loads. Their surface finish ca as smooth as that of a fine auto bile, and held within accu limits. Some slight surface irr larities may exist, but these at worst can be limited to long wa of very low magnitude which not adversely affect the drag.

In summary, it may be said a parasite drag reduction of at l 30% may be obtained through use of the new low-drag airf which, to the best of the auth knowledge, can only be built proper accuracy and finish Heliarc welded magnesium, if m is to be used.



Due to the many demands for Thermit in war production, we are not always able to supply all of the Metal & Thermit metals and alloys made by the Thermit alumino-thermic process.

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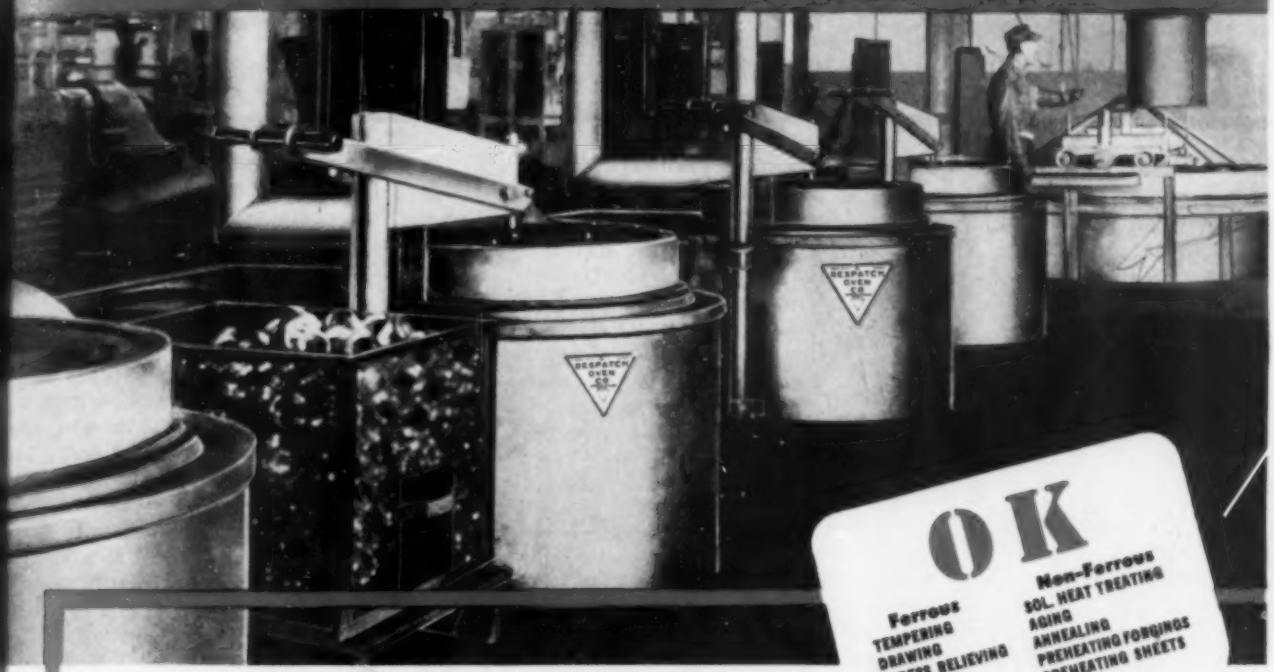

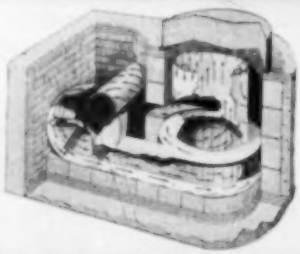

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HANDLES MORE JOBS as accurate performance, speed, heat uniformity are maintained thru entire heat range to 1250° F. Gives added utility by eliminating need of "special type" furnace. Economical to operate and outstanding in efficiency. Gas or electrically heated models; standard sizes to 60" basket diameter.

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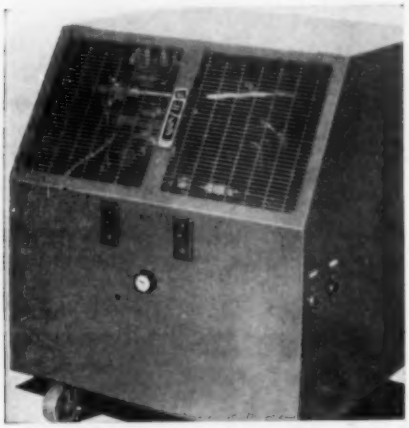
DESPATCH OVEN COMPANY MINNEAPOLIS

New Products

New Industrial Fluid Cooler

A portable fluid refrigerating system is now offered industry by Gray-Mills Co., Chicago. This new addition to their line is a mechanical refrigerator for fluids, and also



settles and screens out chips and the coarser abrasives. Circulation to the work is provided by a self-contained pump. This system is adaptable for coolants for metal cutting, quenching oils and other uses.

New Bending Device

New portable, hydraulic pipe bending machine, known as Tal's Prestal, produces smooth, even bends on iron and steel bar and pipe in one simple operation. No heating or filling is said to be required, with no fractures or wrinkling resulting. Bender is manufactured by Tal's Prestal Bender, Inc., Milwaukee 2, Wis.

Stop-Off Paint

A stop-off paint for selective carburization in liquid carburizing baths has been developed by the Park Chemical Co., Detroit. Known as "No-Kase", this compound is said to protect such difficult spots as threaded edges. Applied as a paint, the compound is easily confined to the area where protection is desired and within an hour is sufficiently dry for immersion in the carburizing bath.

Training Manual

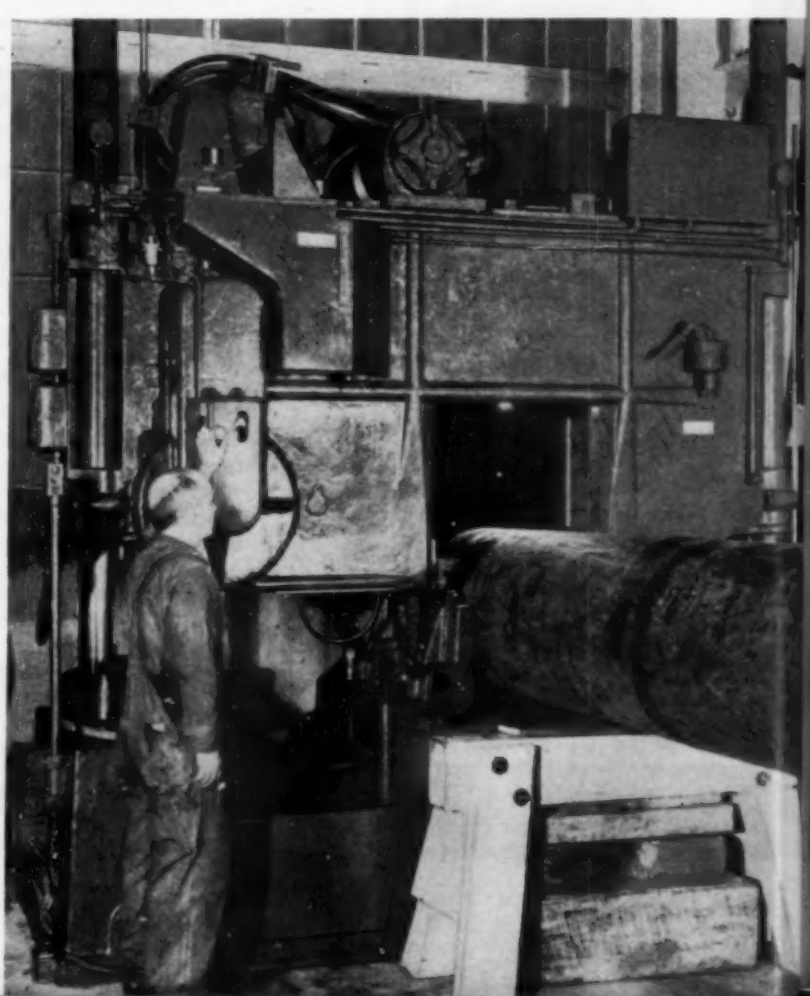
"On-the-Job Instruction of Screw Machine Personnel" is the title of a new 107-page training manual issued by the National Screw Machine Products Assn., 13210 Shaker Square, Cleveland 20, Ohio. Covering all types of multiple spindle automatics, the manual also includes extensive data on grinding and setting tools, and comprehensive trouble charts. Price, $2.

Bonding Lead

New method of readily bonding lead foil or sheet together metallurgically is revealed in patents granted the Reynolds Metals Co., Foil Division, Richmond, Va. New, lead-base, duplex material forms a hermetic seal without any mounting layer or heat-seal coating, because the heat-seal ingredients are contained in the metal itself. low temperature of 350° F. me the surface metal without affecti its lead core, the heat-seal flowi the two surfaces permanently in one solid piece of metal.

Largest Hack Saw

Shown below is No. 24 Marv Universal hydraulic roll-stroke ha saw, working on a 22-in. alloy sha Manufactured by Armstrong-Blu Mfg. Co., Chicago 39, Ill., this thought to be the largest saw ev built. Its nominal capacity is 2 24-in. (maximum 25 x 26 in. Machine weighs 16,000 lb. and co ers a floor space of 56 x 122 in. was developed to cut off or tri large billets, blocks and forgin fast and accurately, thus retaini all the advantages of the hack sa ing method on such large section



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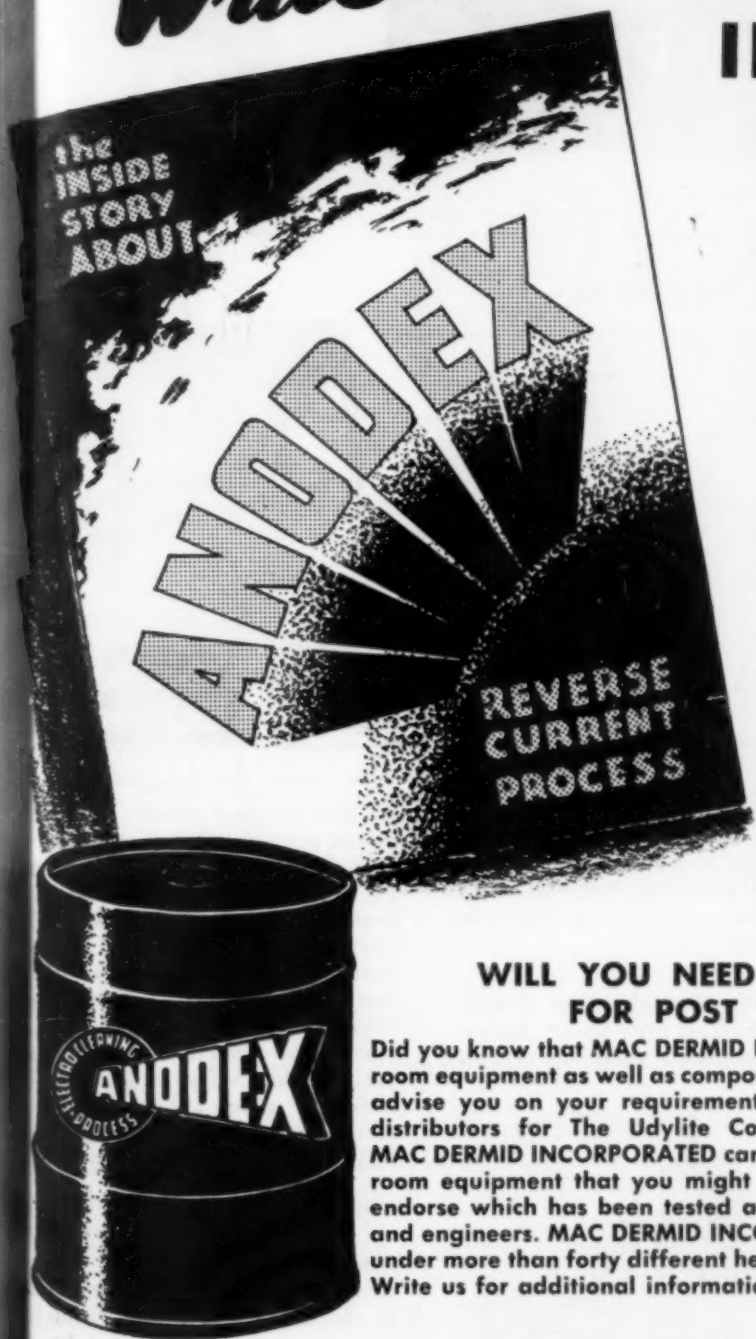
INFORMATIVE NEW FOLDER on Electro-cleaning



MAC DERMID INCORPORATED'S new folder on the ANODEX PROCESS and COMPOUNDS has already proven to be of help to many manufacturers as it briefly explains the principle of this original method of electro-cleaning and tells how to use it to best advantage. If you have not yet received your copy be sure and write for it at once . . . you'll find it more than helpful for post war planning. Also, be sure and write us for our METEX folder describing the many individually formulated METEX compounds that have been developed for fifteen special cleaning operations. A Qualified MAC DERMID INCORPORATED service engineer will be pleased to show you the compound best suited to your need and advise you on how to use it to speed up your production, reduce cleaning costs and improve the cleaning of your product. Special Data Sheets are available on compounds that have been developed for that cleaning job which is "different."

WILL YOU NEED ADDITIONAL EQUIPMENT FOR POST WAR PRODUCTION?

Did you know that MAC DERMID INCORPORATED service engineers sell finishing room equipment as well as compounds and are in an excellent position to expertly advise you on your requirements? Besides being the exclusive New England distributors for The Udylite Corporation plating equipment and processes, MAC DERMID INCORPORATED can furnish you with any type of modern finishing room equipment that you might need . . . equipment that they are proud to endorse which has been tested and approved by their factory trained chemists and engineers. MAC DERMID INCORPORATED products and equipment are listed under more than forty different headings in this directory issue of Metal Progress. Write us for additional information.

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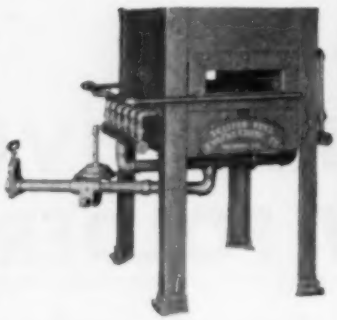

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Rivet Heaters	Soft Metal Furnaces

Eclipse Fuel Engineering Company
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New Products

Cadmium Plate

Cadmium is now being electroplated on base metals in coats more than 50 times as thick as those normally deposited, the Electroplating Division of E. I. du Pont de Nemours & Co., Wilmington 98, Dela., discloses. Such heavy coats on steel sheets are for materials consigned to war production. Approximately 30 lb. of cadmium is being deposited on steel sheets 8 ft. long, over 2 ft. wide and approximately 1 in. thick, in a uniform coat about 0.02 in. thick. Du Pont cadmium anodes and "Cadalyte" cadmium plating salt are used.

Welding Positioner

In the line of welding positioners recently introduced by Harnischfeger Corp., Milwaukee, is a 2500-lb. capacity, Model WP-2, which is said to be priced in the lowest brackets for its class. Featuring adaptability of use, simplicity in construction, and easy operation, it is designed for production line welding. Table is 42 in. diameter, has 18 handy radial slots for mounting fixtures, and is turned manually to suit the welder's speed.

Hydraulic Straightening Press

A sensitive, high speed, hydraulic straightening press has recently

been put into manufacture by Anderson Bros. Manufacturing Co., Rockford, Ill., as a supplement to its line of hand presses. Capaci of the new machine is 10 tons, y it is so sensitive that a shaft m be bent as little as 0.001 in. T pressure gage, which indicates t ram loading, is mounted conve iently near the work at eye level facilitate quantity productio Beneath the ram, at the point maximum deflection of the wo piece, is located an adjustable di indicator which shows the amou of shaft run-out in the pre-loade fully loaded and unloaded positio

Constant Temperature Cabine

An electrically heated, consta temperature cabinet, and consta temperature bath have been adde to the line of explosion-proof la oratory equipment offered by t Precision Scientific Co., 1750 Springfield Avenue, Chicago 47, I Such apparatus is said to be esse tial for safety when handling fla mable or explosive materials, or f operation in a hazardous atmo phere. Heaters are of low watta density for minimum temperatu differential between air and heat surface. Heating elements are ri bon, to allow a large expanse heat-dissipating surface for a giv wattage, and operate at black he

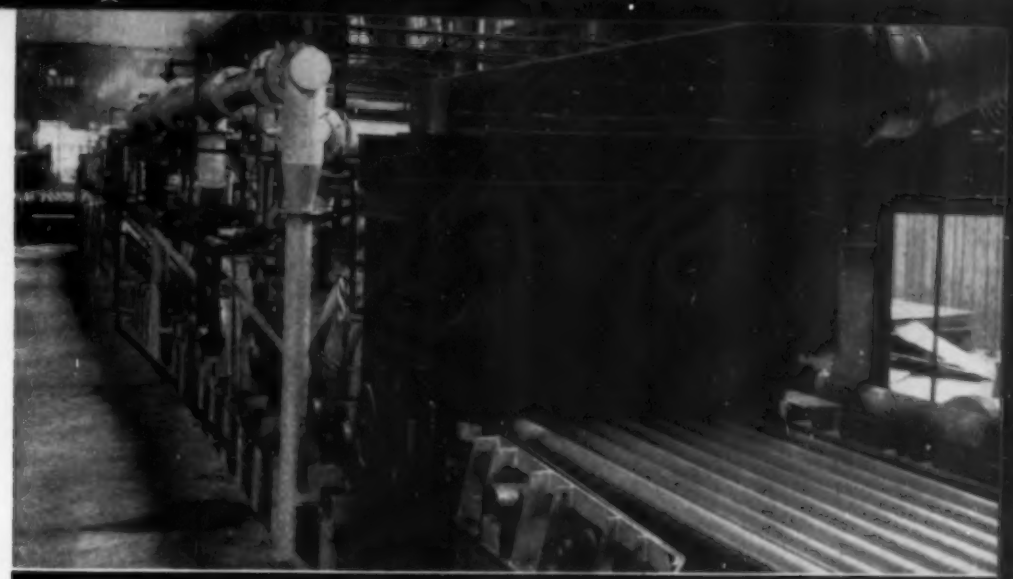
1750° F.

UP

OR

DOWN

800° F.



Tubular Furnace For Tubular Products Holds Close Temperature Uniformity Over 950° F. Range . . . .

This horizontal cylindrical furnace affords excellent heating uniformity over the entire temperature range between draw tempering and normalizing. It handles steel pipe 2 to 14 inches in diameter.

The contour of the heating chamber, which is more than 100 feet in length, eliminates many of the disadvantages with the conventional rectangular design. Above and below the roller driven hearth, burners fire tangentially into the chamber, providing a rapid, swirling action. These hot gases recirculate around the material a great many times, resulting in uniform and efficient heating without hot spots. . . . To raise the furnace from draw temperature to normalizing temperature requires one hour, and only two hours for the reverse cycle, high to low. When normalizing, the furnace heats about 20 tons of pipe in an hour and 18 tons when draw tempering.

Fuel economy is excellent. Other features include two 100 ft. roller tables at either end; five automatic recording temperature zones in the heating chamber; a rayotube instrument which continuously charts the temperature of all tubes being discharged, and two-man operation.

This new-type furnace, including all auxiliary tables, drives, and temperature controls, was designed and installed by Salem Engineering. We can build any type or size of heat treating furnace to your specifications. Write for complete data.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Wall charts and manual sheets have been issued by Firth-Sterling Steel Co. to make easy the selection of color-branded sintered carbides for cutting tools. Bulletin 391.

Marvel metal cutting saws are pictured and described in new booklet issued by Armstrong-Blum Mfg. Co. Bulletin 395.

16-page booklet features 22 short stories of how proper cutting fluids have solved production problems. D. A. Stuart Oil Co. Bulletin 403.

Automatic profilers and hydraulic benders are described in catalogs issued by the Pines Engineering Co. Bulletin 344.

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Cambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Properties, applications and use of hard-facing rods. Coast Metals, Inc. Bulletin 249.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

Handbook on aircraft riveting. Cherry Rivet Company. Bulletin 14.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

New catalog illustrates standard, non-standard, and special tools, shows prices of tools and blanks. Kennametal, Inc. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

20-page booklet on cutting fluids. Tide Water Associated Oil Co. Bulletin 252.

Air tools in steel mills and foundries are pictured in new booklet Ingersoll-Rand. Bulletin 255.

Complete and valuable study "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

Big, comprehensive catalog illustrates line of power presses offered by Minster Machine Co. Bulletin 3

Parsons oval bag dust arrestors described and 12 advantages listed in folder issued by Parsons Engineering Corp. Important advantage is reclamation of valuable dust. Bulletin 228.

FERROUS METALS

ACIPCO Steel—24-page booklet containing a very valuable presentation of the application and properties of this steel is just issued by American Cast Iron Pipe Co. Bulletin 3

Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

Page after page of useful technical data and reference tables on tool steels. Latrobe Electric Steel Co. Bulletin 367.

Aircraft steels, bearing steels. Bulletary Electric Steel Co. Bulletin 2

Use Handy Coupon Below for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 170, 172, 174, 176, 178, 180, 182, 184, 185, 187, 188, 189, 190, 191 and 192

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — January, 194

Send me the Literature I have indicated below.

Name .....**Title** .....

Company .....**Address** .....

(Students—please write direct to manufacturers).

Check or circle the numbers referring to literature described on these 16 pages.

1	35	62	91	116	144	169	193	232	270	315	338	361	384	404
2	38	64	93	117	146	170	196	234	271	316	339	362	385	405
3	40	65	94	118	147	171	197	240	277	318	340	363	386	
4	41	66	95	119	148	172	199	241	281	319	341	364	387	
5	42	67	96	120	149	173	200	242	284	320	342	365	388	
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NEWS OF METAL PROGRESS

AVIATION NOTES

Personnel changes show how metal engineers have stepped into the aviation picture to put metals into the sky.

Joseph Rock, Jr.— now with the tooling research and special assignment section of *Boeing Fortress Plant*

Howard A. Smith — now metallurgical engineer to aid in development work at *Beech Aircraft Corp.*

W. E. Cooper — chief metallurgist of the *Fairey Aviation Co. Ltd.*, also chairman of the war materials committee of the *British Aircraft Industry.*

Anson B. Albree — now in the material division of the *Sikorsky Aircraft Division, United Aircraft*, doing metallurgical work on helicopters.

Leonard C. Peskin — now products engineer, *Kellett Autogiro Corp.*

Jos. N. Reppen — now in plant engineering division, *Dodge Chicago Plant*, Chrysler Corp.

Glenn Sowders — now in charge of heat treating, Illinois Division, *Bendix Aviation Corp.*

James N. Nutt, Jr.— now in the metallurgical laboratories, *Wright Aeronautical Corp.*

E. I. Gardner — now in the manifold department, *Ryan Aeronautical Co.*

Seymour Schwartz — process engineer with *Interstate Aircraft and Engineering Co.*

John A. Holbrook — now doing engineering work on aircraft instruments with *Sperry Gyroscope Co.*

J. L. Waisman — now metallurgist for Chicago plant of *Douglas Aircraft Co.*

George F. Fermier — now with A. J. Brandt Co. as process engineer in the Fort Worth plant of *Consolidated Aircraft Co.*

Louis P. Flesch — now assistant chief metallurgist, *Curtiss-Wright Corp., Propeller Division.*

Chester W. Gates — now general foreman of inspection, outside production, Chicago area, *Boeing Airplane Co.*

GIVING METALS THE AIR

Yes, metal engineers — the intelligence section of the metal industry — are sending efficient, carefully selected and processed metals into the air. For they are responsible for the selection and quality performance of the structural metals, castings, forgings and other metal forms going into America's fighting planes.

This is only natural, for these engineers **know** metals. They know how to judge which metal is best for the job at hand. They know how to prepare this metal for top results — how it should be heat treated, cleaned, finished, welded and otherwise fabricated.

The personal items show the flow of these metal engineers into the aircraft industry — and thousands more are working for metal efficiency in plants supplying this big field.

Metal Progress reaches more metal engineers of this type than any paper in its field. Delivers some 18,000 of them to advertisers at the most economical rate, figured on any basis.

Let's get together and "air" the facts.

ENGINEERING HEADQUARTERS FOR THE METAL INDUSTRY

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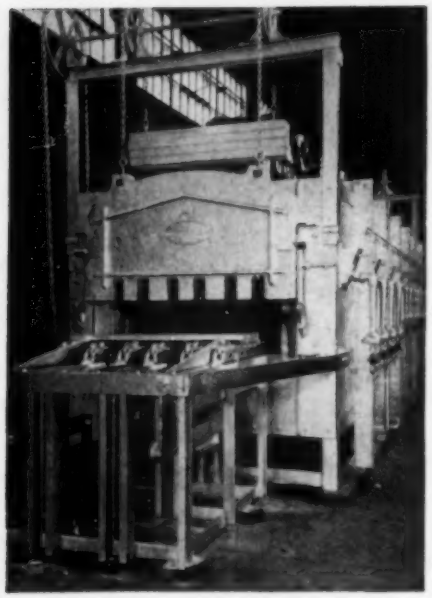

● In the construction of Bellevue Furnaces, painstaking consideration of the job to be done comes first. Every factor must be evaluated, every condition studied. Only then do Bellevue engineers attempt design and recommendation of furnace type.

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Machinery steel selector has been issued by the Elastuf group which includes Horace T. Potts, Brown Wales and Beals, McCarthy & Rogers. Bulletin 256.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Free Machining Steels. Monarch Steel Co. Bulletin 30.

Chemical analyses, shapes and sizes of Joslyn stainless steel products are presented in extras and deductions booklet just issued by Joslyn Mfg. and Supply Co. Bulletin 297.

Tool Steels. Bethlehem Steel Co. Bulletin 31.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Low carbon open hearth case carburizing steel. W. J. Holliday & Co. Bulletin 38.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Kinite alloy tool steel bar stock and its easy handling in heat treatment are described in leaflet by H. Boker & Co., Inc. Bulletin 258.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining, long-wearing steel. Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

Spark Testing Guide—a 21" x 30" wall chart—is useful in segregating tool steel scrap, unscrambling mixed stocks and checking identity of tool steel before heat treatment. Carpenter Steel Co. Bulletin 312.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

Engineering and comparative information on porcelain enameled iron is presented in new illustrated booklet by American Rolling Mill Co. Bulletin 376.

Use Handy Coupon on Page 168 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 168, 172, 174, 176, 178, 180, 182, 184, 185, 187, 188, 189, 190, 191 and 192.

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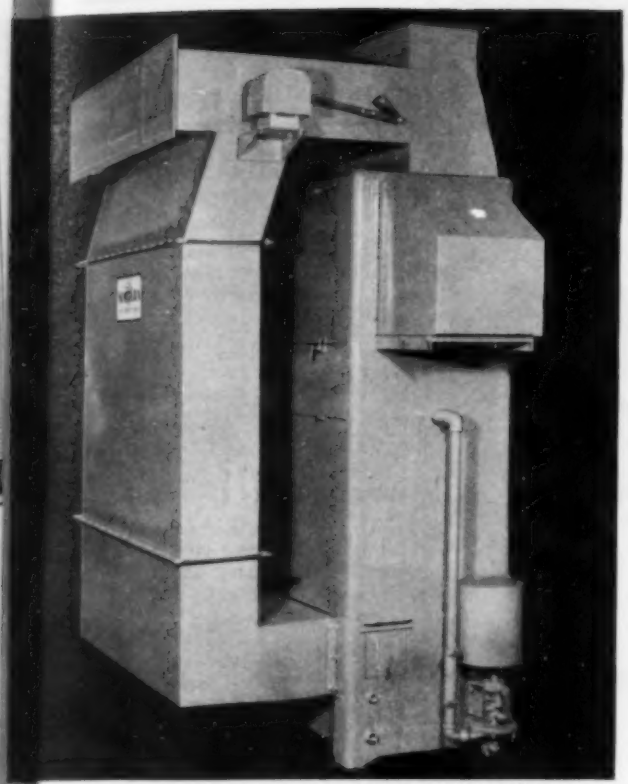
FOR "ROCKWELL" TESTING



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WHAT'S NEW

IN MANUFACTURERS' LITERATI

New booklet gives full informa on N-A-X high tensile and N- 9100 Series of alloy steels. G Lakes Steel Corp. Bulletin 328.

Spindle speed calculator is ha chart to figure machining rate bar steels. Bliss & Laughlin, Bulletin 333.

New handbook on when, wh how and why to use various type stainless steel is offered by Rus Iron and Steel Corp. Bulletin 33

Attractive new catalog descri the line of steel offered by Pe sular Steel Co. Bulletin 337.

Attractive, illustrated 64-page b let describes the welding of stai steels. Allegheny Ludlum Steel C Bulletin 384.

NON-FERROUS METALS

80-page pipe and tube bend handbook has been issued by Co & Brass Research Assn. Bulletin

Reynolds Metals Co. has issued color charts showing marking identification of wrought alumi alloy products, rod, bar, tubing shapes, and for aluminum a sheet. Bulletin 294.

Platinum Metal Catalysts. Bak Co., Inc. Bulletin 41.

Die casting equipment. Le Phoenix, Inc. Bulletin 42.

Bronze. Frontier Bronze C Bulletin 44.

Copper Alloys. American Brass Bulletin 45.

Handy & Harman has issued a vised edition of their general cat on Sil-Fos and Easy-Flo bra alloys. Bulletin 43.

Cerrosafe, a low temperature m ing metal, used to accurately pr cast cavities. Cerro de Pasco C per Corp. Bulletin 47.

"The Story of Magnesium," ill trated booklet by the Permane Metals Corp. Bulletin 261.

Brass and bronze castings. Ha mond Brass Works. Bulletin 48.

Reference on properties of le St. Joseph Lead Co. Bulletin 49.

6th edition of Revere Weights a Data Handbook. Revere Copper a Brass, Inc. Bulletin 296.

Catalog of brass, bronze and i alloys. Cramp Brass and Iron Fo dries Div., Baldwin Locomoti Works. Bulletin 50.

Forgeable tin-free bearing me Mueller Brass Co. Bulletin 53.

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Other Manufacturers' Literature Listed on Pages 168, 170, 174, 176, 178, 1 182, 184, 185, 187, 188, 189, 190, 191 and 1

No better alloy plant than this 11 acre plant exists anywhere.

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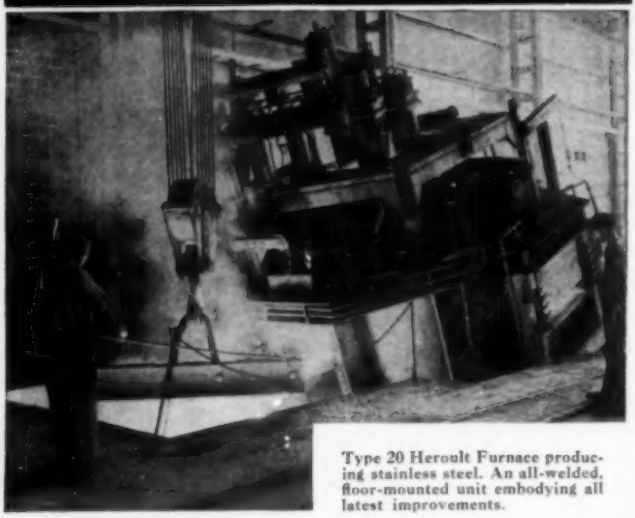

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Surface protection for magnesium. American Magnesium Corp. Bulletin 54.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Brazing Booklet. Westinghouse Elec. & Mfg. Co. Bulletin 57.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

WELDING

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin 60.

Flexarc A-C welders. Westinghouse Electric & Mfg. Co. Bulletin 64.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Shield Arc electrodes. McKay Co. Bulletin 67.

New advances in arc welding equipment design. Harnischfeger Corp. Bulletin 68.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

New 12-page booklet tells how to fabricate fittings for welded piping by means of flame-cutting and welding. Air Reduction Co. Bulletin 234.

New "200" welder is described Allis-Chalmers in Bulletin 260.

Atomic-hydrogen arc welding, application and use, is described General Electric Co. in new Bulle 241.

Welding alloys and metals which they should be used shown in helpful chart form Eutectic Welding Alloys Co. Bulle 242.

32-page catalog describes line welding equipment offered by tor Epuipment Co. Bulletin 245.

Advantages and physical char teristics of "No-Wear", a hard-fac material. Callite Tungsten Corp. letin 251.

Hard Facing Alloys. Wall-Colmo Corp. Bulletin 29.

New 500 lb. capacity welding sitioner for light welding jobs is scribed by Ransome Machinery Bulletin 313.

Two new hard-facing alloys nished as welding rods for appli tion by Oxy-Acetylene process described by the Stoody Co. in B letin 325.

Use Handy Coupon on Page 168 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 168, 170, 172, 176, 178, 182, 184, 185, 187, 188, 189, 190, 191 and

ANOTHER ORIGINAL AJAX DEVELOPMENT!

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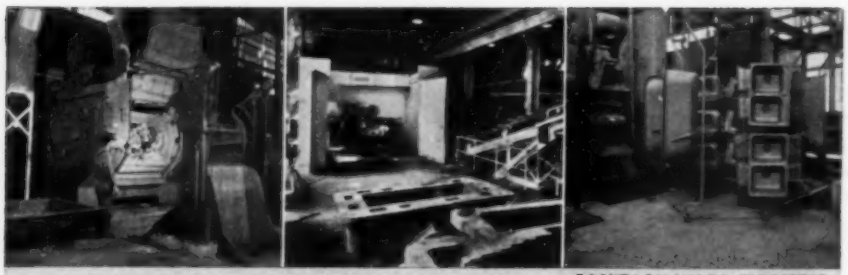

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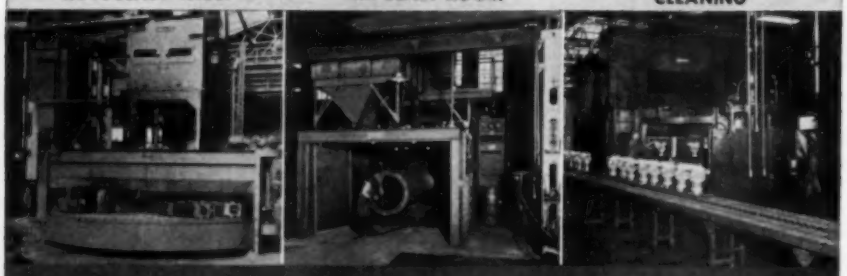

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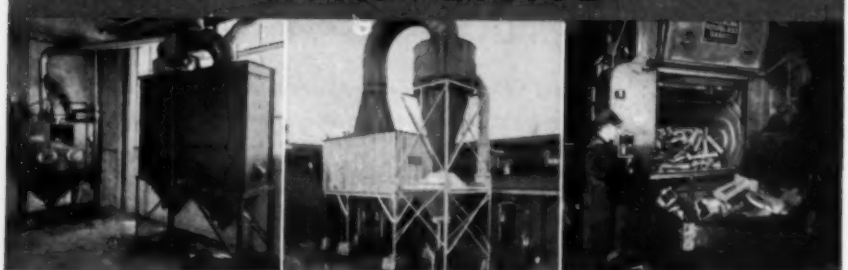

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WHAT'S NEW

IN MANUFACTURERS' LITERATUR

New line of welding positioner with dual capacity are described in new booklet by Harnischfeger Corp. Bulletin 350.

Vest pocket guide to correct welding practices is offered by Hobart Brothers Co. Bulletin 351.

Comparable arc welding electrode for stainless are shown in chart issued by Alloy Rods Co. Bulletin 35[illegible]

Attractive, new booklet describes electric resistance welder for aluminum and its alloys. Sciaky Corp. Bulletin 358.

Helpful electrode color chart offered by the Arcos Corp. Bulletin 374.

TESTING & INSPECTION

Picker X-Ray Corp. has file of four helpful booklets showing line of X-ray equipment and supplies. Bulletin 402.

Bibliography of more than 70 papers dealing with the polarographic method of metal analysis and a booklet discussing this equipment is offered by E. H. Sargent & Co. Bulletin 338.

Various methods and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

Precision production tools such as surface plates, angle plates, straight edges, etc., are described in Catalog No. 42 issued by Acme Tool Co. Bulletin 340.

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71[illegible]

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

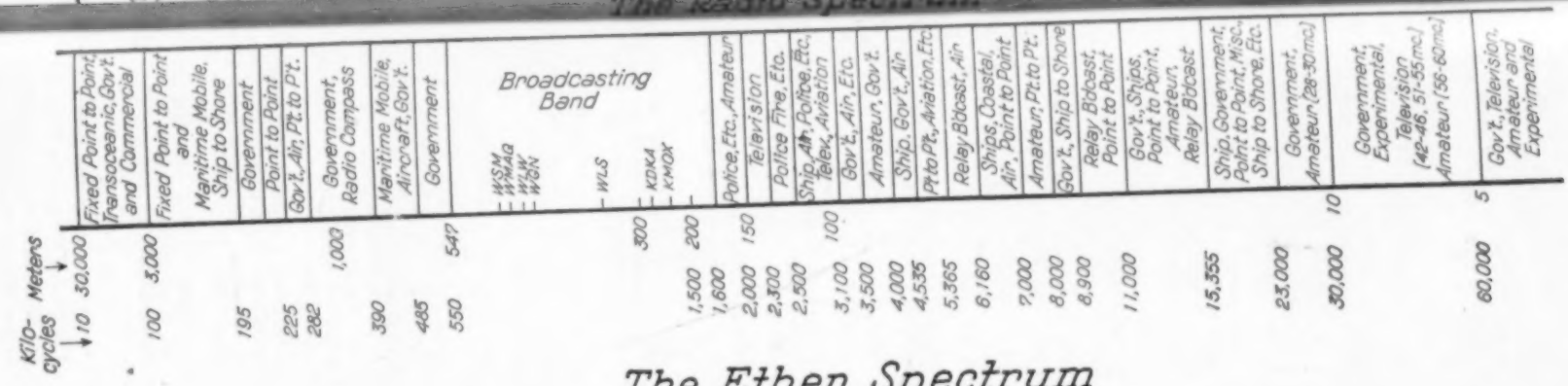
Electric heaters and controls for industrial and laboratory. American instrument Co. Bulletin 75.

Carbon-Meter for rapidly determining carbon at the furnace. E. Leitz, Inc. Bulletin 264.

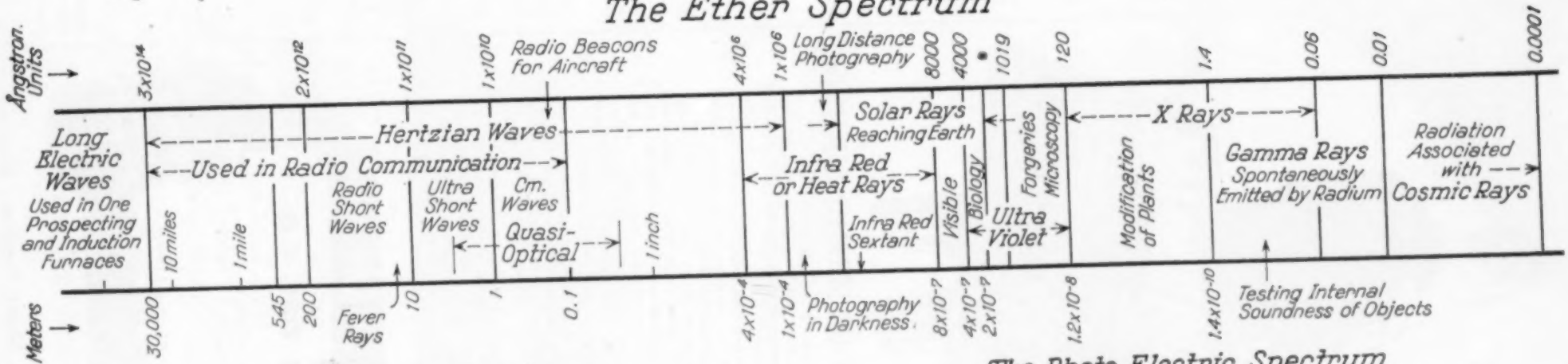
Use Handy Coupon on Page 168 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 168, 170, 172, 174, 178, 18[illegible] 182, 184, 185, 187, 188, 189, 190, 191 and 19[illegible]

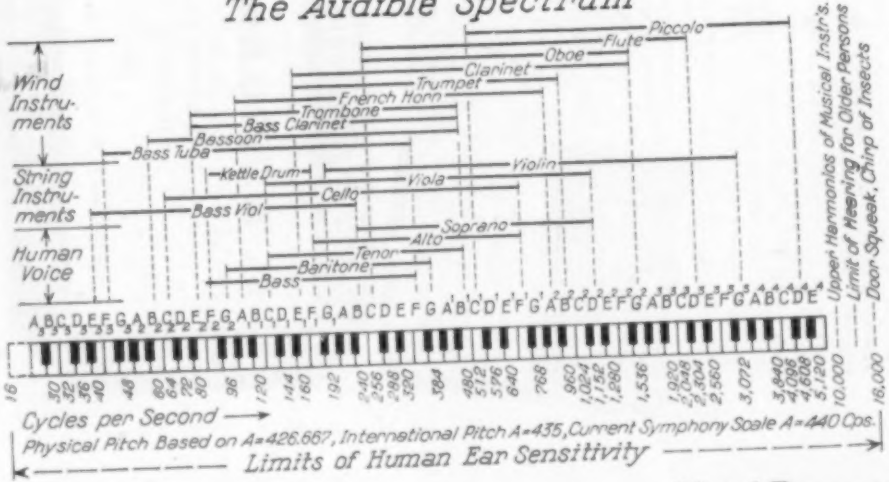
The Radio Spectrum



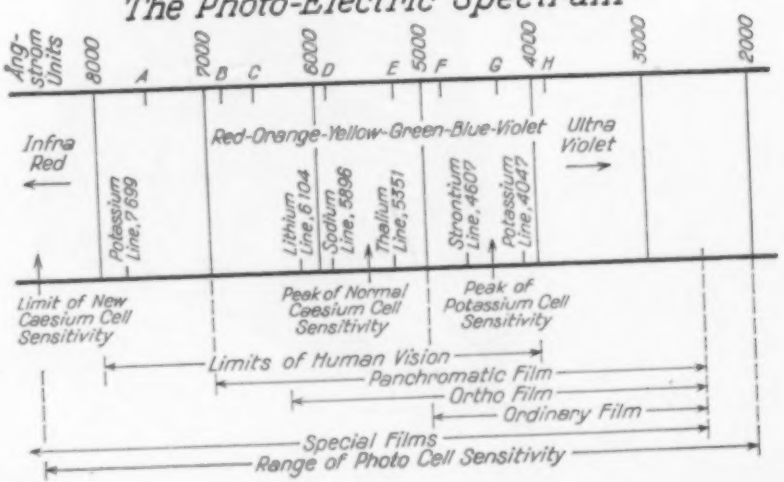
The Ether Spectrum



The Audible Spectrum



The Photo-Electric Spectrum



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CUTTING FLUIDS DESERVE YOUR SERIOUS ATTENTION

Well informed authorities have made the statement that more intelligent application of cutting fluids and better tool grinding would make possible a 30% increase in metal-working production. In these days of man-power shortage, what a challenge that statement presents!

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

Inspection of non-magnetic me with the new Zyglo method. Mag flux Corp. Bulletin 78.

Industrial radiography with dium. Canadian Radium & Urani Corp. Bulletin 79.

Gage blocks, comparators, proj tors. George Scherr Co. Bulletin

Surface Analyzer. Brush Devel ment Company. Bulletin 88.

Portable Brinell hardness tester folding Brinell microscope. Andr King. Bulletin 85.

Universal testing machines typical uses. Riehle Testing Machi Div., American Machine and Met Inc. Bulletin 86.

Dillon tensile tester and the Dil dynamometer. W. C. Dillon & Bulletin 91.

Optical Aids. Bausch & Lomb tical Co. Bulletin 94.

Coleman universal spectrophot eter. Wilkens-Anderson Co. Bul tin 95.

Metallographic polishing pow Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Ado I. Buehler. Bulletin 97.

Hardness testing equipment. W son Mechanical Instrument Co., Bulletin 98.

Identometer for rapid identifi tion of steel. Dravo Corp. Bulle 267.

Attractive, illustrated booklet scribes Clark Instrument's precis hardness tester. Bulletin 318.

"Radiography of Materials" is t of new 96-page book on industr radiography. Eastman Kodak Bulletin 331.

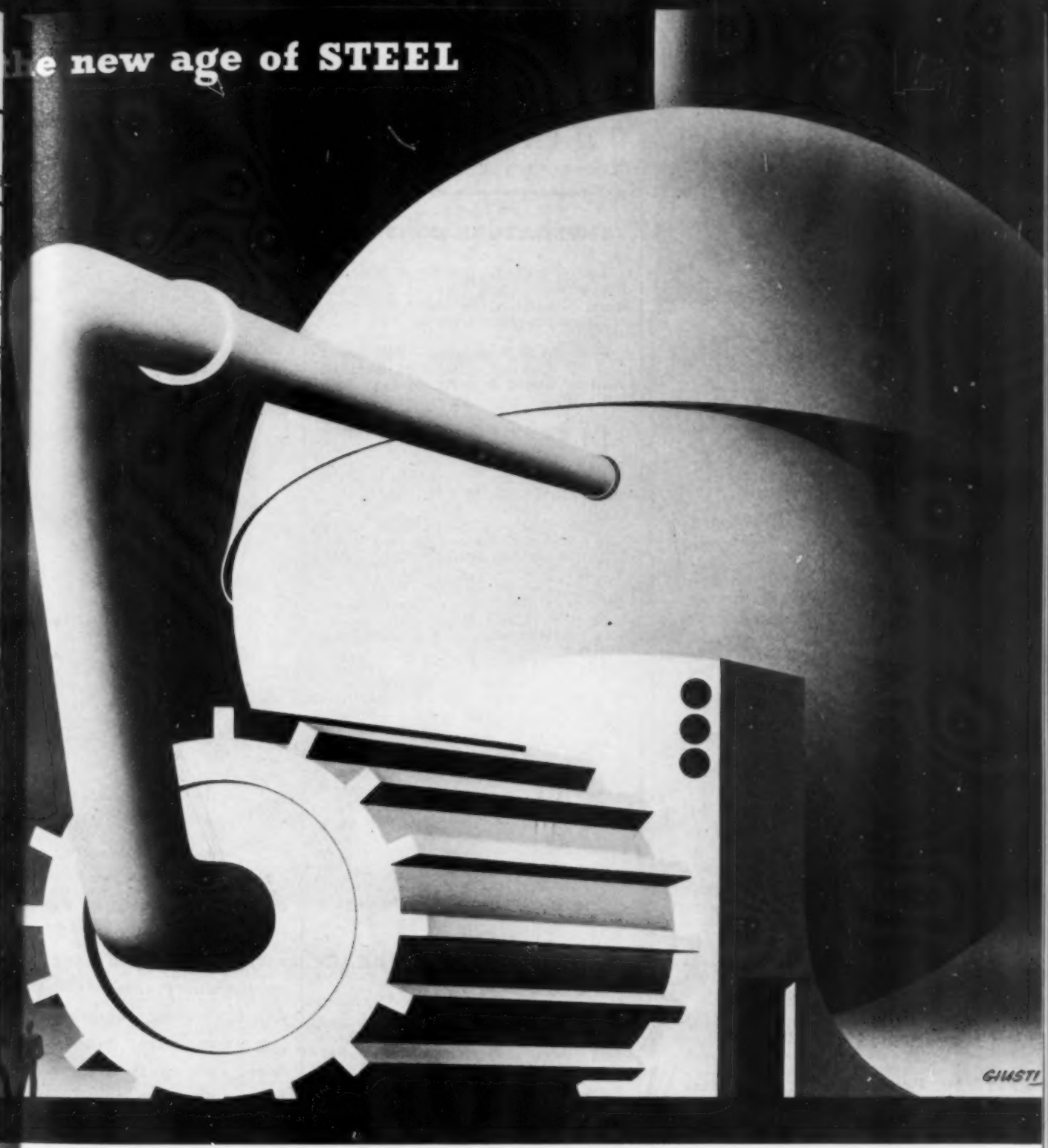
Eberbach micro hardness teste illustrated and described in booklet by Eberbach & Son Co. letin 269.

Moisture determinations of a w range of materials with new Moist Teller instrument are described new leaflet by Harry W. Dietert Bulletin 299.

Stresscoat, a method of analyzi distribution, direction and value local strains. Magnaflux Co Bulletin 301.

Two new folders describe Sear ray 80, new self-contained X-ray u of North American Philips Co. letin 377.

Use Handy Coupon on Page 168 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 168, 170, 172, 174, 176, 182, 184, 185, 187, 188, 189, 190, 191 and



The experiment of today leads to the accepted practice of tomorrow. Enterprise is an attribute of leadership. For seventy-five years Midvale has been a partner of industry in the creation of new tools and processes, casting, forging and finishing steel to implement the ideas of progressive engineering. When the problem seems most difficult, then is the time when Midvale research and Midvale experience prove their greatest worth.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

TEMPERATURE CONTROL

8-page bulletin describes Wheelco Instruments Co.'s line of Potentiotrols. Explains the electronic principle employed. Bulletin 389.

New 29-page catalog — Micromax Electric Control — has just been issued by Leeds & Northrup Co. Bulletin 76.

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin 89.

Pyrometer control of high speed salt baths is described in new booklet by Brown Instrument Co. Bulletin 324.

40-page booklet contains useful technical information on thermometry and thermometers. Bristol Co. Bulletin 321.

New file folder service bulletin on Weaver Furnace Atmosphere Indicator. Claud S. Gordon Co. Bulletin 332.

Industrial thermocouples. Arklay S. Richards Co. Bulletin 93.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin 84.

New leaflet describes valve operator of industrial operation of valves, dampers and other control devices. Automatic Temperature Control Co. Bulletin 381.

HEATING • HEAT TREATMENT

Surface Combustion has issued practical booklet for those who have only recently experienced essentiality of heat treating. Bulletin 392.

Equipment for determining the quantity of sodium cyanide in molten cyanide mixtures used in heat treatment is described in new bulletin by the Kocour Co. Bulletin 394.

Sectional hairpin heat exchangers are described in new leaflet issued by Brown Fintube Co. Bulletin 396.

24-page technical data and operating manual covering the Deepfreeze low temperature industrial chilling machines has been issued by Deepfreeze Div., Motor Products Corp. Bulletin 398.

Use Handy Coupon on Page 168 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 168, 170, 172, 174, 176, 178, 182, 184, 185, 187, 188, 189, 190, 191 and 192.

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Resistant to Acid Corrosion and Heat

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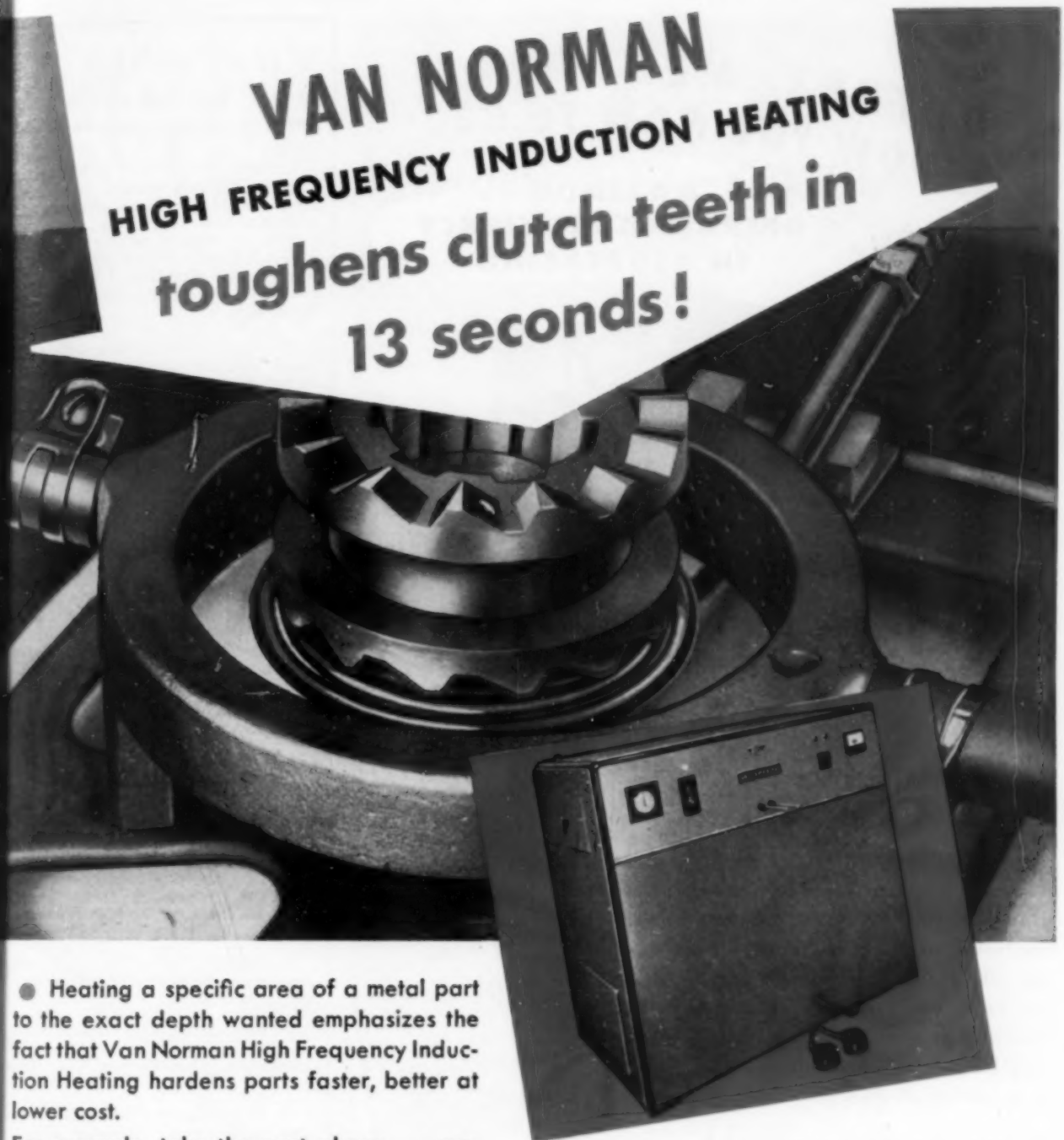

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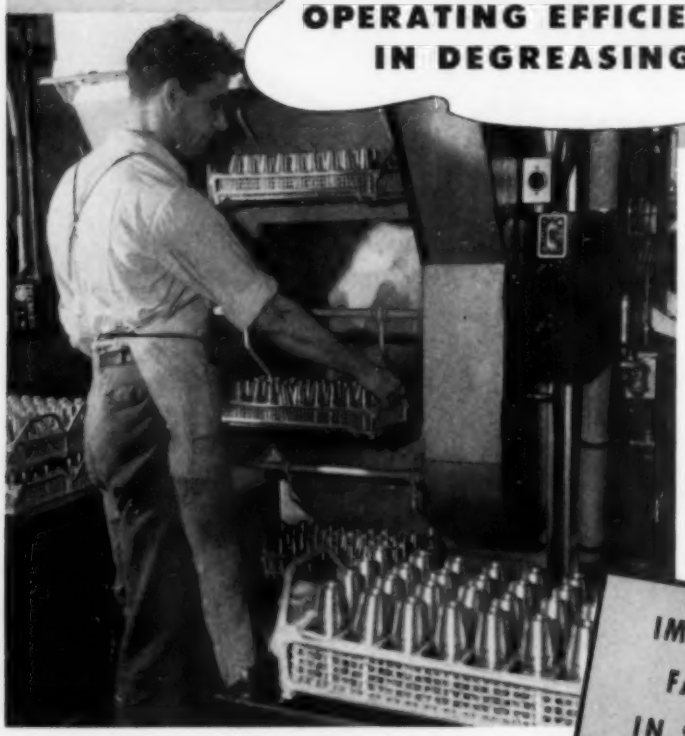

As with any mechanical equipment, degreasers must be properly installed, operated and maintained. While the majority of manufacturers using degreasers have personnel capable of proper handling of the machines, some details may be overlooked with a resulting loss in operating efficiency.

Detrex Service Men cooperate with and instruct the engineers, chemists and operators responsible for your metal cleaning. Among the factors which they cover are those listed at the right. This continuous "follow through" is available to all Detrex customers.

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

Classifications and applications heat treating salts are described new leaflet by G. S. Rogers & Bulletin 400.

Heat treatment of light metals Surface Combustion furnaces is scribed in new 8-page leaflet. letin 405.

36-page catalog illustrates K Hold line of thermal, sub-zero stratosphere processing and tes machines. Kold-Hold Mfg. Co. B tin 99.

Induction heating. Induction H ing Corp. Bulletin 103.

Internally heated salt bath furna and pots. Upton Electric Furn Div. Bulletin 102.

Easy-selection charts on burning equipment. National chine Works. Bulletin 105.

8-page pictorial bulletin descri the heat treating service of Co nental Industrial Engineers, Inc. letin 107.

Electric Furnaces. Ajax Elect thermic Corp. Bulletin 106.

Homo method for nitriding is scribed and illustrated in new page catalog by Leeds & Northr Bulletin 100.

Lithco, the chemically-neutral treating process, and Lithcarb, process for fast, bright gas-carbu ing. Lithium Corp. Bulletin 10

Centrifugal blowers and exha ers. Roots-Connersville Blower C Bulletin 270.

Furnaces for heat treatment of minum, magnesium and their all Lindberg Engineering Co. Bull 271.

Rotary Hearth Furnaces. Lee son Sales Corp. Bulletin 290.

Gas, oil and electric heat trea and carburizing furnaces. Holc & Co. Bulletin 114.

Industrial furnaces, equipment bright annealing stainless steels ammonia dissociation equipm Drever Co. Bulletin 115.

Industrial ovens, rod bakers, w ing rod ovens, furnaces. Carl-Ma Corp. Bulletin 116.

Full muffle and other heat trea furnaces described in catalog Charles A. Hones, Inc. Bulletin

Use Handy Coupon on Page 168 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 168, 170, 172, 174, 176, 180, 184, 185, 187, 188, 189, 190, 191 and

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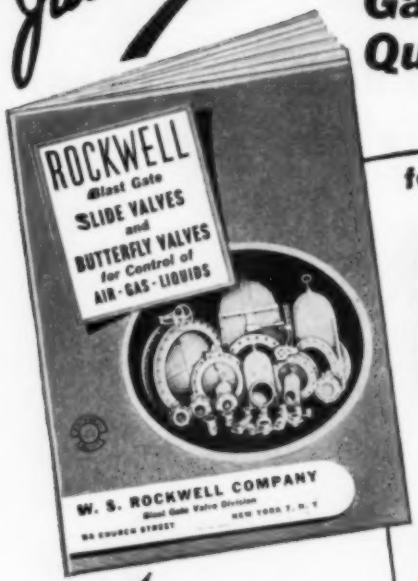

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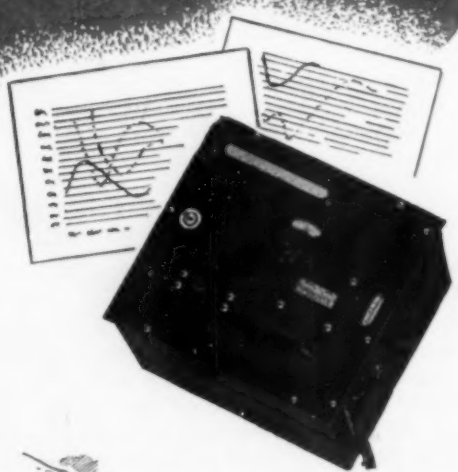


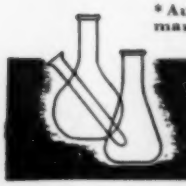
Time saving procedures, using Coleman Spectrophotometers* are shown in the new and revised "Curves and References". Molybdenum, phosphorus and manganese references are also given.

One user reports "... *copper, nickel and molybdenum determinations are done in 20 minutes using the UNIVERSAL, as compared to 90 min. formerly required.*"

Write for Bulletin 1-MP and ask also for detailed procedure on the new copper and nickel method!

*Authorized Coleman Distributors

Turning one knob permits selection of any color light band required . . . Coleman Universal Spectrophotometer, at $340.00 — replaces visual and filter colorimeters.



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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Non-metallic Electric Heating ... ments. Globar Div., Carborundum Co. Bulletin 119.

56-page vest pocket data book ... heat treating practices and procedures. Chicago Flexible Shaft ... Bulletin 118.

24-page catalog describes gas ... and electric Holden heat treating ... furnaces, and baths. A. F. Holden ... Bulletin 120.

Modern electric furnaces for ... treating. Harold E. Trent Co. in ... Bulletin 121.

Control of temperatures of quen... ing baths. Niagara Blower Co. ... letin 122.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Tocco hardening, brazing, anne... ing and heating machines. ... Crankshaft Co. Bulletin 124.

Handling cylinder anhydrous am... monia for metal treaters. Armour Ammonia Works. Bulletin 128.

Industrial Furnaces. W. S. Rock... well Co. Bulletin 133.

Certain Curtain Furnaces. C... Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportion... flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

Two new bulletins on vertical c... burizers and on carbonia fini... American Gas Furnace Co. Bulletin 139.

Van Norman induction heating units. Van Norman Machine Tool Co. Bulletin 144.

Gas-air premix machine. Eclipse Fuel Engineering Co. Bulletin 1...

Controlled atmosphere furnaces. Delaware Tool Steel Corp. Bulletin 141.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Furnaces. Tate-Jones Co. Bulletin 142.

Industrial Carburetors. C. M. Kenyon Mfg. Co. Bulletin 143.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Use Handy Coupon on Page 168 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 168, 170, 172, 174, 176, 180, 182, 185, 187, 188, 189, 190, 191 and ...

WHAT'S NEW
MANUFACTURERS' LITERATURE

Vertical Furnace. Sentry Co. Bulletin 148.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

High and low temperature direct fired furnaces. R-S Products Corp. Bulletin 146.

New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

Furnace Experience. Flinn & Dreffein Co. Bulletin 153.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Dehumdifier. Pittsburgh Lectro-Dryer Corp. Bulletin 155.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin

15-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin 160.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

Protective combusted atmospheres Hevi Duty Electric Co. furnaces are discussed in 12-page Bulletin 316.

Turbo-Compressor data book shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.

Catalog of heat treating materials. Gleathbath Corp. Bulletin 322.

Besides high-speed steel hardening, Kinz Electric Co. Bulletins 110 and 107-A cover the equally impressive Kinz performance in carburizing, neutral hardening, etc. Bulletin 342.

Photographs and drawings are used to describe car type quick-reveal oven by Whiting Corp. Bulletin 355.

Use Handy Coupon on Page 168 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 168, 170, 172, 174, 176, 178, 180, 182, 184, 187, 188, 189, 190, 191 and 192.

It's What The User Says About Heat Treating Containers That Counts!

A producer of heat treating containers might, like any other manufacturer, wax overenthusiastic about his product, advancing claims based on what he has designed it to do. But what really counts is the performance of those containers in actual service, preferably as reported on by users. Accordingly, we will let users of Amsco Alloy heat treating pots write the balance of this message.

"The cyanide pot you furnished, your blueprint number SD-2385, has now been in service nine months. If you will recall, we felt that to equal the operating cost of a steel pot (not alloy) the cast alloy pot would have to stand up at least four months. Since the Amsco Alloy pot has gone twice that period, its life has been quite satisfactory. The pot is still in active service and at the time of the last examination there was no evidence of prospective failure."

* * *

"Your Amsco Alloy pot has been in service 2,600 hours and seems to be in good shape, even though certain others of another make and apparently of the same analysis lasted 1,000 hours or less."

* * *

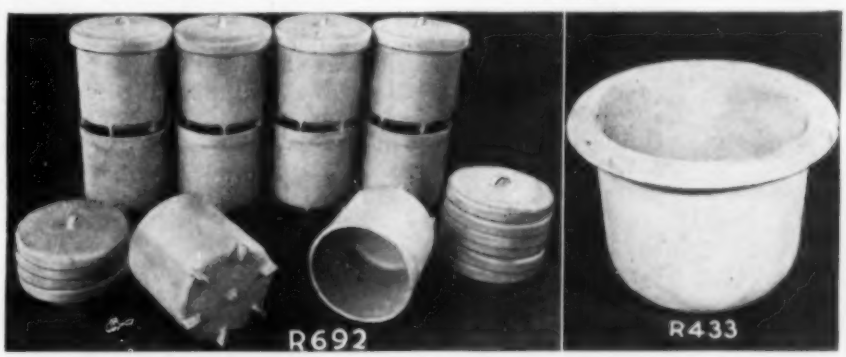
"Our Amsco Alloy pots handling neutral salts have given us the best service of any that we have ever used."

Nothing much to be added to the above, except that the names of the users may be had on request, and that heat and corrosion-resisting Amsco Alloy containers are available in a wide range of types and sizes for every heating and heat treating application.

Ask for Bulletin 1041-A.

R-692. One piece carburizing containers and covers.

R-433. A 20" x 20" cyanide pot, X-ray inspected and pressure tested.



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Edited by John Wulff

Department of Metallurgy, Massachusetts Institute of Technology

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Standardized sizes of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

Use of pulverized coal in the metallurgical industries, equipment and designs, are described by Amsler-Morton Co. in Bulletin 361.

Illustrated bulletin on stress-relieving car-type furnaces. Radiant combustion. Bulletin 375.

Furnaces for heat treating tools, jigs and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

Rapid oil coolers and heat transfer equipment are described in new catalog issued by Bell & Gossett Co. Bulletin 365.

New book "Hardness" describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

New booklet describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

New leaflet describes and illustrates heat treat furnaces of McCann Furnace Co. Bulletin 379.

32-page catalog describes in detail General Electric heat treat furnaces. Bulletin 380.

Laboratory and tool room furnace. Kanthal Mfg. Co. in new Bulletin 327.

Four basic heat treating atmospheres are described in new booklet by Westinghouse. Bulletin 383.

War Production Data — 30 pages of useful information on metal working, heat treating and other metal producing operations just issued by L. F. Houghton & Co. Bulletin 387.

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Cromox, new protective refractory coating material for prolonging life of firebrick, insulating firebrick, and castable refractories. Federal Refractories Corp. Bulletin 163.

Use Handy Coupon on Page 168 for Ordering Helpful Literature.
Other Manufacturers' Literature listed on Pages 168, 170, 172, 174, 176, 178, 180, 182, 184, 185, 188, 189, 190, 191 and 192.

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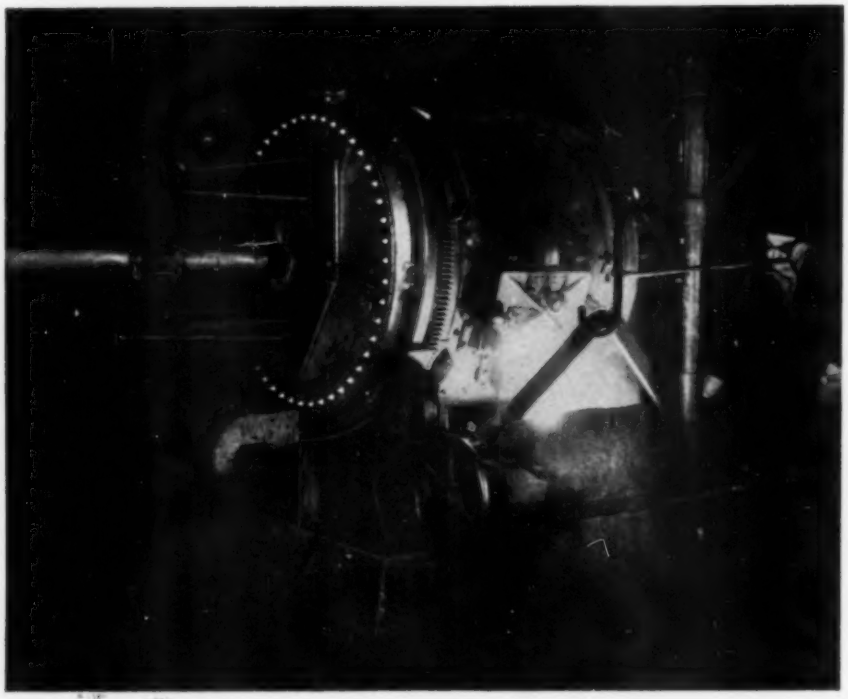

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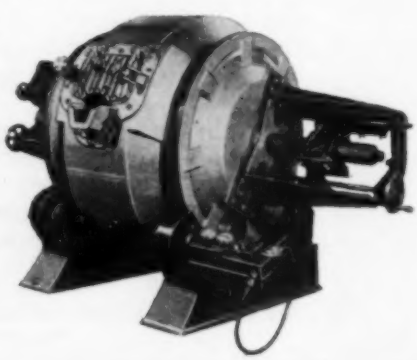

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Heavy Duty Refractories. No... Co. Bulletin 164.

Super Refractories catalog. C... rundum Co. Bulletin 165.

Interesting data sheets on Th... O-Flake insulating bricks and ... ings. Illinois Clay Products Co. ... letin 298.

Ramix bottom for basic o... hearth furnaces. Basic Refracto... Inc. Bulletin 168.

Conductivity and heat trans... charts. Johns-Manville. Bulletin ...

Brickseal refractory coating. B... seal Refractory Co. Bulletin 16...

D-E insulating materials and t... application are described in ... data booklet by Armstrong Cork ... Bulletin 208.

Corhart Electrocast Refracto... for the melting and refining of n... are described by Corhart Refr... tories Co. Bulletin 209.

Zircon refractories in alumi... open hearth furnaces are discus... in new leaflet by Chas. Taylor S... Co. Bulletin 347.

H-W magnamix, a Washington ... nesite ramming mixture for ... hearth and electric steel furnaces ... described in new leaflet by Harbi... Walker Refractories Co. Bulletin ...

Charts to simplify solution of h... transfer problems in refractories ... high temperature insulation ... shown in new 16-page booklet ... Atlas Lumnite Cement Co. Bulle... 378.

FINISHING • PLATING • CLEANING

Enthone Co.'s emulsion cleaner ... described in new bulletin 393.

Automatic and semi-automatic p... ing equipment for a variety of pr... esses and products are illustrated ... 40-page booklet issued by Frede... B. Stevens, Inc. Bulletin 397.

Roto-Finish equipment for ... burring, buffing, polishing and co... ing. Sturgis Products Co. Bulle... 170.

Use Handy Coupon on Page 168 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 168, 170, 172, 174, 176, 180, 182, 184, 185, 187, 189, 190, 191 and ...

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

A protective, deep black finish to steel. Heatbath Corp. Bulletin 171.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Pickling. Wm. M. Parkin Co. Bulletin 174.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 175.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment. Detrex Corporation. Bulletin 175.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin 212.

Airless Rotoblast. Pangborn Corp. Bulletin 176.

Cadmium Plating. E. I. duPont de Nemours & Co., Inc. Bulletin 177.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin 179.

Catalog on finishing and cleaning. Frederick Gumm Chemical Co., Inc. Bulletin 292.

Resilon corrosion-resistant tank linings and applications are described in 8-page leaflet by United States Stoneware Co. Bulletin 291.

"Indium and Indium Plating". Indium Corp. of America. Bulletin 182.

Service report describes use of Oakite machining, drawing, degreasing and descaling materials. Oakite Products, Inc. Bulletin 210.

Metal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin 213.

Catalog section on new sheet Koroseal linings for tanks of welded steel, wood or concrete has been issued by the B. F. Goodrich Co. Bulletin 112.

Lead plating is discussed in new booklet issued by Harshaw Chemical Co. Bulletin 109.

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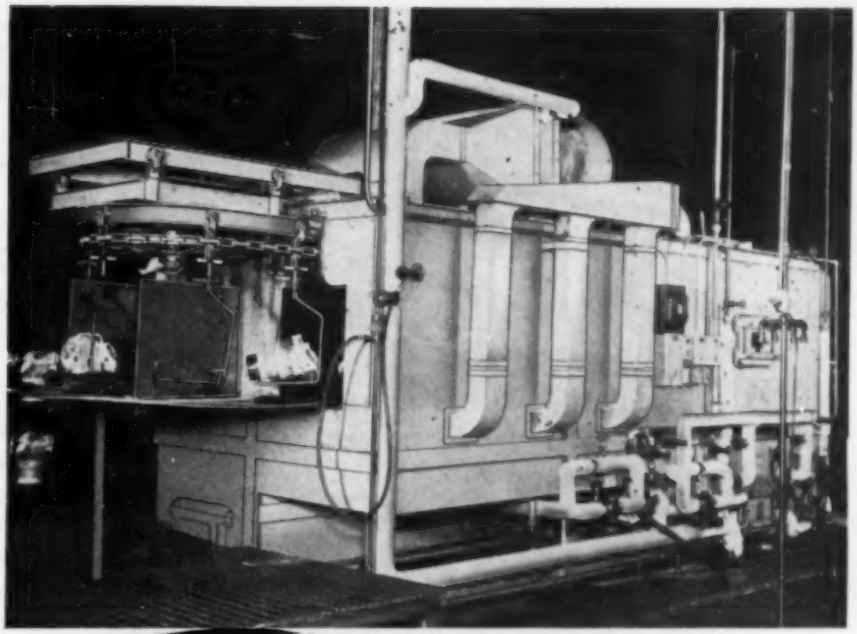

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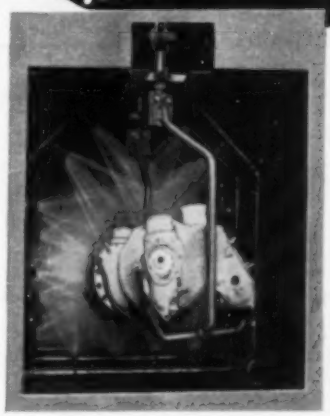

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Catalog shows typical cleaning and finishing machines engineered and built by Howard Engineering & Mfg. Co. Bulletin 110.

Four types of solvent degreasers and cleaners are described in new leaflet by Technical Processes Div., Colonial Alloys Co. Bulletin 230.

Discussion of anodizing, chromatizing and phosphatizing in illustrated 60-page book has been issued by Turco Products, Inc. Bulletin 243.

Revised edition of "The American Line", 20-page reference catalog of entire line of products manufactured by American Foundry Equipment Co. has just been released. Bulletin 341.

112-page manual describes Chemicals by Glyco. Glyco Products Co. Bulletin 346.

Cleaning castings and forgings at low cost by tumbling is described in leaflet by Whiting Corp. Bulletin 356.

Illustrated booklet describes blast cleaning equipment offered by Ruemelin Mfg. Co. Bulletin 360.

ENGINEERING • APPLICATIONS • PARTS

New 32-page illustrated booklet contains much data on manganese steel for the railroad industry. American Manganese Steel Div. Bulletin 388.

Illustrated leaflet presents data and uses of special alloys resisting corrosion, high temperatures and abrasion. The Duraloy Co. Bulletin 390.

Catalog gives complete specification data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

Heat treating fixtures for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.

Pressed steel pots are described by Bell & Gossett Co. in new Bulletin 364.

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

54-page booklet, "File 41—E neering Data Sheets", gives comp facts on Ampco Metal's phy properties and service record. letin 368.

New information sheets on tap and formed tubes have just issued by Summerill Tubing Co. letin 369.

Chace manganese alloy No. 77 sheets, strips, rod and special sh described by W. M. Chace Co. letin 190.

Electrical, corrosion and heat sisting alloys in rod, wire, rib and strip forms. Wilbur B. Dr Co. Bulletin 192.

Meehanite Castings. Meehanite search Institute. Bulletin 196.

X-Ray Inspected Castings. Ele Alloys Co. Bulletin 197.

Steel Castings. Chicago Steel F dry Co. Bulletin 199.

Heat Resisting Alloys. General loys Co. Bulletin 200.

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Bimetals and Electrical Contacts. H. A. Wilson Company. Bulletin 202.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin 206.

Alloy Castings. Ohio Steel Foundry Co. Bulletin 207.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics, issued by Drop Forging Assn. Bulletin 240.

24-page catalog is guide to properties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 319.

Details of new Chemicast process for small brass parts will be supplied by Chemicast Div., Whip-Mix Corp. Bulletin 330.

MELTING • CASTING • MILL OPERATIONS

Attractive new 52-page booklet describes Moore rapid Lectromelt furnaces for iron, steel, nickel and copper melting and refining. Pittsburgh Lectromelt Furnace Corp. Bulletin 404.

Cradle furnace which produces a homogeneous gray iron of uniform chemical analysis, uniform temperature and controlled carbon content is described by Whiting Corp. Bulletin 357.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin 186.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin 137.

Crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin 183.

Ingot Production. Gathmann Engineering Co. Bulletin 185.

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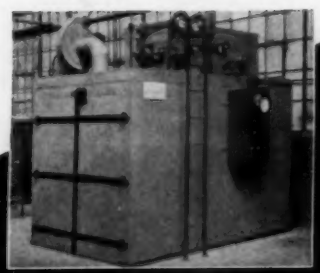

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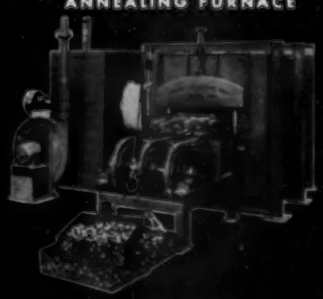

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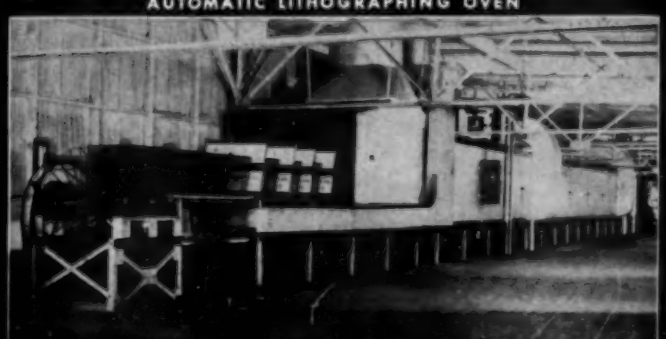

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Manganese-Titanium Steels. T nium Alloy Mfg. Co. Bulletin 18

Chrom-X for steel mill and fo ry. Chromium Mining & Smel Co. Bulletin 187.

Electric Furnaces. Detroit Elec Furnace Div., Kuhlman Electric Bulletin 189.

Stroman crucible melting furn for aluminum and magnesium described in leaflet by Stro Furnace & Engineering Co. Bull 277.

Operating Features, capacit charging methods of the He electric furnace. American Bri Co. Bulletin 215.

Chart for the correction of bra for zinc loss should interest foun men. Foundry Services, Inc. letin 217.

Coke oven plant construction development in 1942 is descri and illustrated in 12-page pamp by the Koppers Co. Bulletin 232

"Fisher Magnesium Scrapbo Fisher Furnace Co. Bulletin 281.

Attractive booklet descri growth, facilities and offers valu alloy hints. Niagara Falls Smel & Refining Corp. Bulletin 246.

Vertical centrifugal casting chine for production of ferrous nonferrous castings is described Centrifugal Casting Machine Co. Bulletin 315.

Interesting, descriptive leaflet metal reclaiming mill offered Dreisbach Engineering Corp. Bu tin 284.

GENERAL

Available material of the U.S. A Air Forces is shown in catalog iss by 830th Army Air Force Specialt Depot. Bulletin 401.

New leaflet describes interof communication system offered Executone Communication Syste Bulletin 385.

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